OCULUS | Perimeter


# Perimeter Guide

revised edition

OCULUS®

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# Perimeter Guide

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Note: This Interpretation Guide has been translated from German. The case studies cited originate from the individual studies of experts who contributed to this Interpretation Guide. For this reason the illustrations shown in the Interpretation Guide have been left in German, as have the units of measure.

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# Content

# Preface

This short guide cannot and is not supposed to replace a study of the professional perimetry literature, nor is it a manual to any one of the OCULUS perimeters. Its purpose lies between these two. It is intended to provide some detailed knowledge on the OCULUS perimeters on the one hand and clinical information on the other. In some parts the guide will read like a general clinical textbook of perimetry, in others more like a manual and sometimes it will be neither. There is more to using a perimeter effectively than just pressing the right buttons; understaning examination results is essential. For this purpose the guide provides a link between knowledge acquired through medical training and the information covered in the relevant manuals. It is intended to help you perform visual field examinations competently and extract all the relevant information contained in their results.

# Acknowledgments

Perimetry has for long been and continues to be a standard discipline of ophthalmology in both private practice and hospital settings . In 1957 Professor Heinrich Harms, then director of the Ophthalmological Clinic of Tübingen University, together with Professor Dr. Elfriede Aulhorn, his assistant medical director, originated the principles of static perimetry, thus contributing to the development of a far more precise method of examining the central visual field than had been possible before. Its strategy is still today the standard approach used by automated perimetry systems around the world.

The first Tübingen Automatic Perimeter, developed jointly by the Ophthalmological Clinic of Tübingen University and OCULUS, was presented in 1980 at the DOG (Deutsche Ophthalmologische Gesellschaft – German Ophthalmological Society) in Kiel. Among the basic features of this instrument were a pattern of test points arranged with increasing density towards the centre and adapted levels of stimulus luminance. Today's generation of OCULUS perimeters, the Twinfield® and the Centerfield®, have much more to offer, but they too, are based on the original strategies of static perimetry.

The name of Professor Dr. Aulhorn has retained its ring of authority in the field of perimetry. She was a co-developer of many perimetry seminars. Cooperating with her was as much a challenge as it was a pleasure. Our thanks also go to Ms. Friedlinde Dorner-Schandl with her long years of experience as a perimetrist, and to Mr. Wilhelm Durst, both of whom worked together with Professor Dr. Aulhorn for many years. This team has greatly supported us to this day in all matters of perimetry.

Another contributor to the numerous strategies incorporated in OCULUS perimeters is Professor de la Rosa from Teneriffa. Our sincere thanks go also to him for his expert services in integrating the TOP Strategy into the Octopus Perimeter and the improved SPARK Strategy into the OCULUS perimeters.

Rainer Kirchhübel

Managing Director

OCULUS Optikgeräte GmbH

# 1. Introduction

## 1.1. Why Automated Perimetry?

Broadly speaking, perimetry examinations can serve three different purposes: the diagnostics and differential diagnostics of diseases affecting the visual pathway; by derivation, the follow-up of patients with such diseases; and thirdly, the preparation of expert opinions such as for driver aptitude tests.

From a rudimentary understanding of the human visual field one might at first suppose that its function is determined above all by the outer limits to which it extends from the central line of sight. However, closer study reveals that it is much rather the distribution of sensory sensitivity within the visual field that determines its integrity. Many diseases first become noticeable within an angle of 30° around the central line of sight. Automated perimeters allow sensitivity measurements to be performed in any direction up to 90° from the fovea, depending on the model. Moreover, automated examinations are fast, convenient to run, and can be easily delegated to appropriately trained examiners.

## 1.2. Static or Kinetic Perimetry?

There are two basic approaches to automated perimetry: static and kinetic perimetry. In static perimetry a stimulus (usually a white light spot) is briefly presented to the patient at a specific location while the patient looks straight ahead at a defined fixation point. The stimulus is presented in a defined size and brightness level relative to the background illumination. The patient's task is to report whether or not they saw the stimulus. By increasing or decreasing the brightness of the stimulus the instrument can gather information on the patient's light sensitivity regarding the point being analyzed. This test is repeated at many points within the area being examined. From the results obtained a map is generated that represents the visual field of the eye being examined .

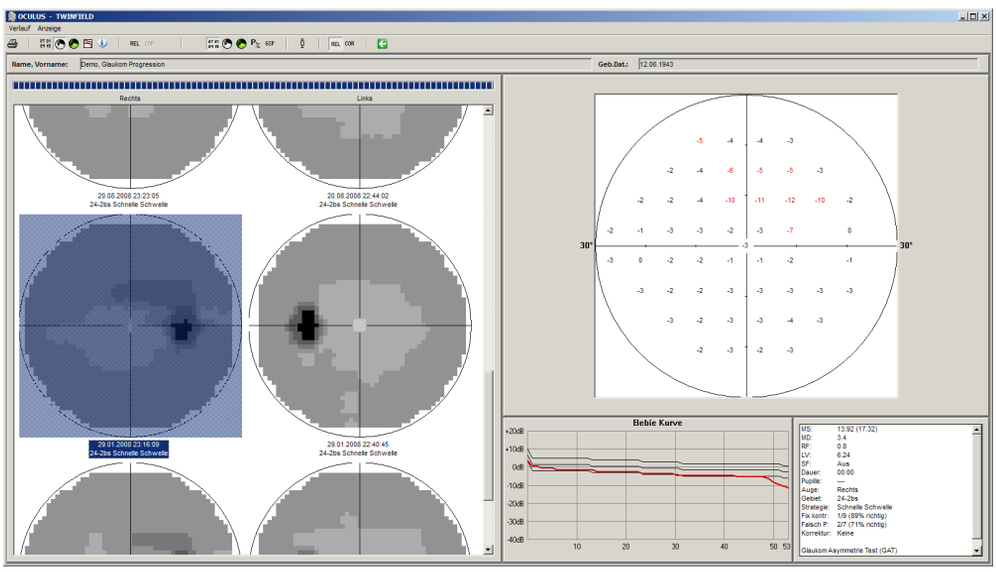


Figure 1, Twinfield trend

In kinetic perimetry a stimulus of defined size and brightness is moved towards the point of fixation from different directions (usually 12) until it is detected by the patient. In this way 12 locations is obtained of equal sensitivity which can be joined to a line representing that level of sensitivity. These lines, also referred to as isopters, liken to contour lines contour lines of constant altitude on a geographic map. By using stimuli of different intensities one can generate isopters at different distances from the point of fixation and ultimately obtain a sensitivity map of the entire visual field.

For a normal visual field a minimum of 4 to 5 isopters are determined along with the blind spot. The easiest way to locate the blind spot is by using a small, bright stimulus such as one of Goldmann size I 4e.

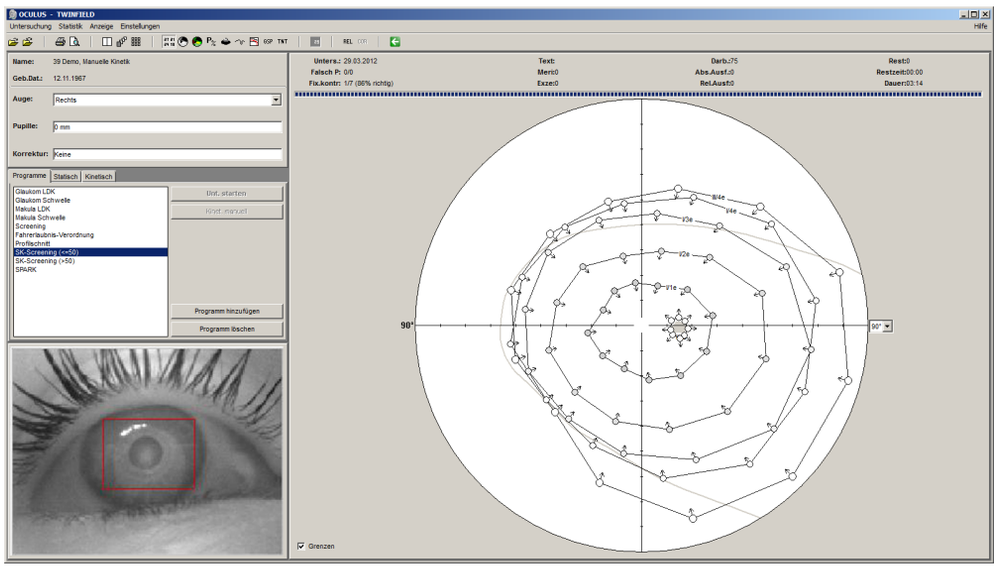


Figure 2, Twinfield Kinetik

## 1.3. The OCULUS Perimeters

OCULUS Optikgeraete GmbH, based in Wetzlar, Germany, produces four different automated perimeters, named the Smartfield, Easyfield®, Centerfield® and the Twinfield®.

The smallest of these, the Smartfield, allows static perimetric examinations up to 30°/25° eccentricity, i.e., including fixation shift, up to of 60°/50°. The stimulus is displayed on an LCD screen in Goldmann size III (Referenz zu Goldmann Kap.3). A darkroom can be dispensed with thanks to the instrument's closed design.

Another compact instrument in the OCULUS line of perimeters is the Easyfield®. It allows static perimetry examinations up to 30° eccentricity using a bright white stimulus of Goldmann size III against a white background.

The Centerfield® is suited for static perimetry examinations up to 70° eccentricity. This has been made possible by using a fixation shift to extend the instrument's physical opening angle by 35°. Its examination repertoire includes kinetic perimetry of the central visual field as well as blue-yellow perimetry (where a blue stimulus is presented against a yellow background). The Centerfield® comes with a Goldmann size III stimulus.

The Twinfield® is the largest of the four instruments. Its repertoire includes static perimetry up to 90° eccentricity without fixation shift, kinetic perimetry (automatic kinetic perimetry or manual kinetic perimetry according to Goldmann) and colour perimetry (either blue-yellow perimetry or perimetry with red stimuli). Visual field tests on the Twinfield® are performed with stimuli of Goldmann sizes I, III and V.

The OCULUS perimeters also differ in the way the stimuli are presented. The Easyfield® makes use of fixed test patterns of light emitting diodes (LEDs) to generate light spots. The Smartfield performs static perimetry measurements using an LCD display of very high luminance to create a standard background illumination, onto which the test stimuli are projected.

By contrast, the Centerfield® and Twinfield® models make use of a back surface projection system with which stimuli can be presented at any desired point on the projection screen. Back surface projection systems have the advantage of being able to project circular stimuli onto any desired location, making them suitable for kinetic examinations.

# 2. History of Perimetry

While automated perimetry is still quite a young technology, only dating back to the 1970s, the basic principles of visual field examination can be traced back several thousand years to the era of ancient Greece. The following sections give a brief account of the history of perimetry, with a special emphasis on its development at OCULUS.

## 2.1. General History of Perimetry

The first record of a visual field examination originates from Hippocrates (430-380 B.C.). In it he described a case of visual field loss which today would be classified as hemianopsia. Leonardo da Vinci (1452-1519) observed that the visual field extends beyond 90° temporally. In 1668 Mariotte discovered the physiological blind spot and, relying on his good intuition, correctly conjectured that it had to do with the papilla. The symptoms of a scotoma were first described in 1708 by Boerhouve. The term is derived from the Greek word „skotos", meaning darkness. The outer boundary of the visual field was first described by Young in 1801, whose observations were revised by Purkinje already in 1825.

In 1856 came a real breakthrough when Graefe introduced visual field testing into medical practice, earning fame as the acclaimed "father of clinical perimetry". He was also the first to observe sector defects, curtain defects, enlarged blind spots and central scotomas and to create a first systematic classification of visual field defects.

The rapid growth in understanding clinical phenomena relating to the visual field was soon paralleled by the development of examination methods. In 1857, only one year later, Aubert and Förster designed the first arc perimeter.

In 1945 Goldmann developed the first bowl perimeter, which permitted accurate checking of fixation and retinal adaptation as well as control of stimulus size and intensity. He also defined standards for the size and intensity of light stimuli. In hindsight this was the last step into the age of visual field testing as we know it today.

At around the same time Heinrich Harms was engaged in developing techniques for static perimetry using stationary targets. After moving to Tübingen in 1952 he continued his pursuits, later to be supported in his work by Elfriede Aulhorn. In the meantime Louise Littig Sloane in the USA was also working on techniques of static perimetry.

## 2.2. History of Perimetry at OCULUS

Development work in perimetry has a long tradition at OCULUS, beginning with the manufacture of the Förster perimeter more than 100 years ago. In 1957 the company began to cooperate more closely with the Eye Clinic of Tübingen University. The goal was to develop an instrument for examining the visual field. 1959 saw the presentation of the first perimeter perimeter, a result from this cooperation: the Tübingen Hand Perimeter (Figure 4, First prototype of the Tübingen Automatic Perimeter, 1976). This extremely complex instrument was built more than 300 times and distributed worldwide until 1985. It was the first perimeter that allowed both kinetic and static perimetry, and its spatial resolution of the central visual field up to 30° eccentricity was three times greater than the standard for the Goldmann perimeter at that time. It already contained all the technical principles implemented in almost every automated static perimeter on the market today.

Figure 3, The Tübingen Hand Perimeter

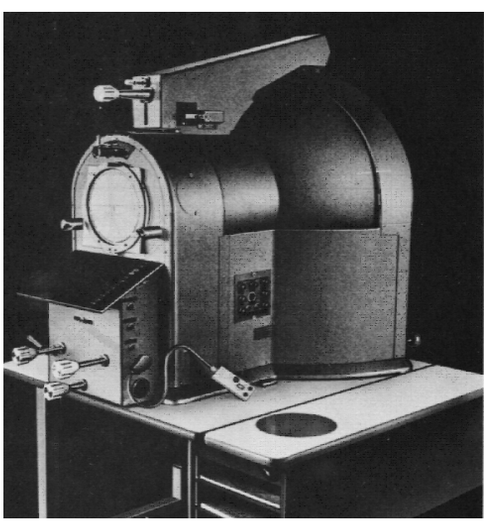

Figure 5, The Tübingen Hand Perimeter

In 1976 the first prototype of the Tübingen Automatic Perimeter was presented at the IPS (International Perimetric Society – now called the Imaging and Perimetry Society) meeting in Tübingen (Figure 4, First prototype of the Tübingen Automatic Perimeter, 1976).


Figure 4, First prototype of the Tübingen Automatic Perimeter, 1976

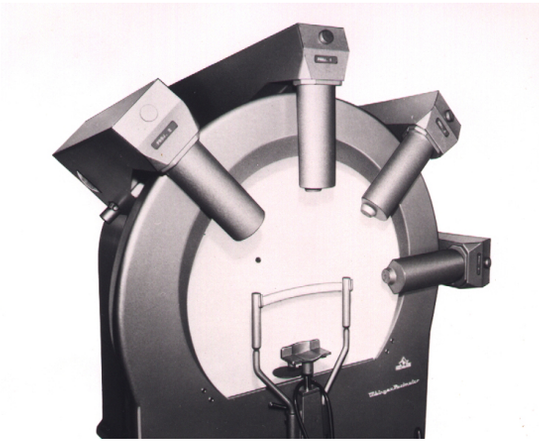

Figure 6, First prototype of the Tübingen Automatic Perimeter ,1976

It was developed in cooperation with the Eye Clinic of Tübingen University and the Institute of Information Transmission of Stuttgart University of Technology based on the techniques implemented in the Tübingen Hand Perimeter.

The first commercially available Tübingen Automatic Perimeter (TAP) was presented in 1980 at the DOG annual meeting in Kiel. This was the first OCULUS perimeter that was computer-controlled and thus capable of performing automated visual field examinations (Figure 6, First prototype of the Tübingen Automatic Perimeter ,1976).

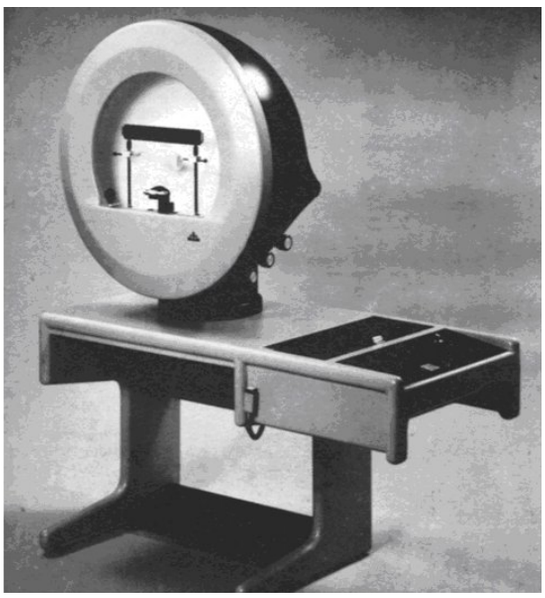

Figure 7, The Tübingen Automatic Perimeter (TAP) of 1980

Subsequent development work on the original TAP led to two follow-up models: the TAP 2000 in the year 1985 and the TAP 2000 CT in 1990.

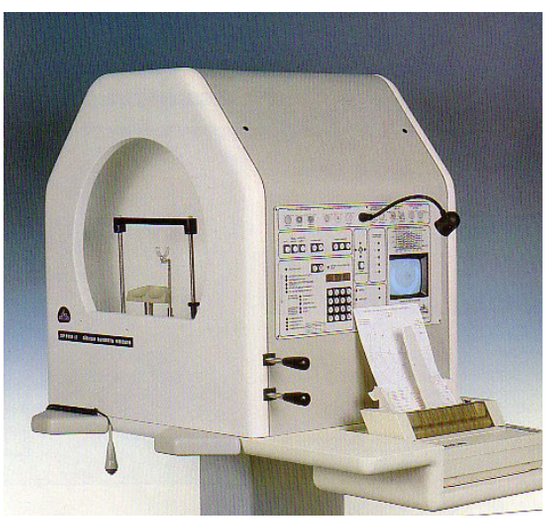

Figure 8, The TAP 2000 CT

In 1995 OCULUS released the Twinfield®, the first instrument that allowed computer controlled static as well as full kinetic perimetry.

The Twinfield® has remained the flagship of the range of OCULUS perimeters until today. Completing the range are the Centerfield®, the Easyfield® and the Smartfield perimeters.


Figure 9, Twinfield®, Easyfield®, Centerfield®, and Smartfield perimeters

# 3. Fundamentals of Perimetry

Perimetry is the systematic measurement of visual field function. It is a subjective examination method, since it relies heavily on the cooperation of the person being examined. A thorough understanding of the fundamentals of perimetry is indispensable for the appropriate selection of tests to be used, correct performance of the examination and proper interpretation of its results.

## 3.1. Luminance

The term luminance stands for an objective photometric measure of the luminous flux per unit area emitted by an illuminant in a given direction. In the International System of Units (SI) luminance is measured in candela/$m^2$ (cd/$m^2$). Another commonly used unit of measure is the apostilb (asb), which originates from the pre-automation era of perimetry. Conversion between these two units obeys the formula 1 asb = 0.3183 cd/$m^2$[1]. With present-day perimeters it is common practice to include the background luminance and maximum stimulus luminance in the technical specifications. All OCULUS perimeters have a background luminance of 10 cd/$m^2$ (31.4 asb), in conformity with the Goldmann standard. Maximum stimulus luminance is 318 cd/$m^2$ (1 000 asb) in the OCULUS models Centerfield® and Twinfield®, as required by the Goldmann standard, and 3180 cd/$m^2$ (10 000 asb) in the Smartfield und Easyfield® perimeters.

### 3.1.1. The Luminance Decibel Scale

The human eye is capable of processing luminance levels within the range from 0.001 cd/$m^2$ (moonless night with an overcast sky) to about 100 000 cd/$m^2$ (fresh snow in full sunlight). The sensory capacity of the human visual system thus spans 8 to 9 orders of magnitude. Luminance levels beyond the high end of this range, such as from direct sunlight, may cause irreversible damage to the retina. To be able to deliver meaningful examination results perimeters must therefore be capable of generating light stimuli across a wide luminance range. In most instruments stimulus luminance spans 4-5 orders of magnitude.

In view of the wide dynamic range, stimulus luminance in perimeters is commonly expressed not as an absolute physical quantity, in units of cd/$m^2$, but giving its relative magnitude compared to a reference level. This reference level is conventionally the perimeter's maximum stimulus luminance (which is 318 cd/$m^2$ in the Twinfield® and 3 180 cd/$m^2$ in the Easyfield®)[2]. The resulting quotient and the relative magnitude is given on a decibel (dB) scale.[3] The reference value thus comes to lie at the zero point on the decibel scale. On the Twinfield® perimeter, for example, 0 dB is equivalent to a stimulus luminance of 318 cd/$m^2$. According to this convention a measured value of 10 dB is equivalent to a stimulus at a tenth of maximum stimulus luminance, and 20 dB to one at one hundredth that value etc. We are dealing here with a logarithmic representation. For example, a reduction of the luminance level by half will show up on the decibel scale as an increase by ca. 3 dB.

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1 This conversion facftor follows from 1 asb = $1/\varpi$ cd/$m^2$.

2 Conversion formula: $\Delta L=10*\log(L_{ref}/\Delta L)$ ($\Delta L$ and $L_{ref}$ both expressed in cd/$m^2$ in the ratio).
The log value of any number less than 1 is negative.
$\Delta L$: luminance difference, i.e. difference between stimulus luminance and background luminance.

3 A stimulus of luminance L is represented by $L_{rel} = 10 \cdot \log (L_{max} / L)$ on the decibel scale. It follows from this convention that luminance values are always positive on a decibel scale.

One should bear in mind that two stimuli with the same absolute luminance may have different luminance values on different perimeters, since the luminance scale also depends on device-specific characteristics. For example, a stimulus of 10 cd/m² will measure 25 dB on the Easyfield®, but only 15 dB on the Centerfield® or Twinfield®. Therefore it is very important to know the reference luminance value of the perimeter being used.[4]

### 3.1.2. Luminance Threshold

The luminance threshold in a given location of the visual field is the range of transition from the luminance values of stimuli that can no longer be detected to those that are always detected. Since this transition is not abrupt, but rather extends over a certain luminance range, the luminance threshold is conventionally defined as the luminance value of a stimulus that has a 50% probability of being seen.

There are two essential properties of the luminance threshold one should always keep in mind. First, it is a statistical quantity, and its determination will therefore always be subject to statistical variation. This means that individual measurements for the same patient same patient will always differ to some degree and that the true luminance threshold will be best represented by their average. Secondly, the sharpness of the transition from undetectable to invariably visible stimuli depends on the threshold level. The general rule is that a high luminance threshold (on the decibel scale) is associated with a sharp transition. Normal threshold values have a transition range of 3 – 4 dB, while pathological values can be associated with a transition range of 10 – 12 dB.

Whereas the general properties of the luminance threshold are independent of stimulus size (i.e. area) or duration, the numerical value of the threshold is not. In practice one should therefore always use standard stimuli in order to be able to objectively compare measured threshold values *(see* 3.1.4. Goldmann Stimulus Sizes and Luminance Values *)*.

### 3.1.3. Differential Luminance Sensitivity

By convention, the differential luminance sensitivity (DLS) in a given location of the visual field is defined as the luminance threshold value (expressed in dB) in that location. As already explained in the chapter on the luminance decibel scale *(*3.1.1. The Luminance Decibel Scale*)*, low luminance values (weak light stimuli) appear as high values on the perimetric decibel scale. The ability to detect a weak stimulus requires high sensitivity. This relationship is illustrated in Figure 10, Light Difference Sensitivity (LDS). The lower boundary of the measurable range of sensitivity is determined by the perimeter's maximum stimulus luminance, i.e. the absolute level equivalent to 0 dB, and therefore depends on the instrument being used.

4 To convert from one instrument-specific decibel scale to another one only needs to shift the measured values by a certain constant. This constant is easy to calculate, provided the reference values of the two perimeters are known. Conversion between the Easyfield® and the Centerfield® is done by increasing or diminishing all measured values by 10 dB.

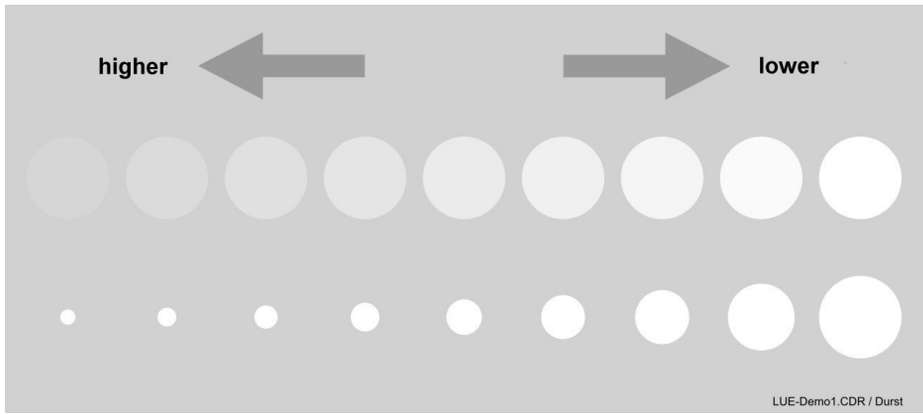



Figure 10, Light Difference Sensitivity (LDS)

### 3.1.4. Goldmann Stimulus Sizes and Luminance Values

In his pioneering work Hans Goldmann defined a set of standard stimuli that serves as a key parameter in comparing the results of visual field tests performed on different perimeters (see Figure 11, Goldmann Test Points). When arranged in order of their numbering (0 to V) the angle subtended by each stimulus doubles and the area of each increases fourfold from one to the next. In kinetic perimetry it is common practice to plot 4 to 5 isopters across 12 meridians. This is considered to provide a sufficiently detailed image of the visual field for clinical purposes. The test stimuli are selected such that the resulting isopters will be distributed as evenly as possible. The preferred procedure is to use a Goldmann size I stimulus of different brightness levels, i.e. I4e, I3e, I2e and I1e. Stimulus size III is of particular relevance to visual field testing for medical opinion purposes.

Goldmann also defined stimulus brightness levels on the luminance scale, the maximum luminance being 318 cd/m$^2$ (1000 asb) according to his definition. He divided the resulting decibel scale into four regions, (logarithmic decades), numbered 1 through 4, and each of these into five intervals designated a through e (Figure 11, Goldmann Test Points). According to this convention a stimulus of 12 dB luminance is designated 2c, for example.

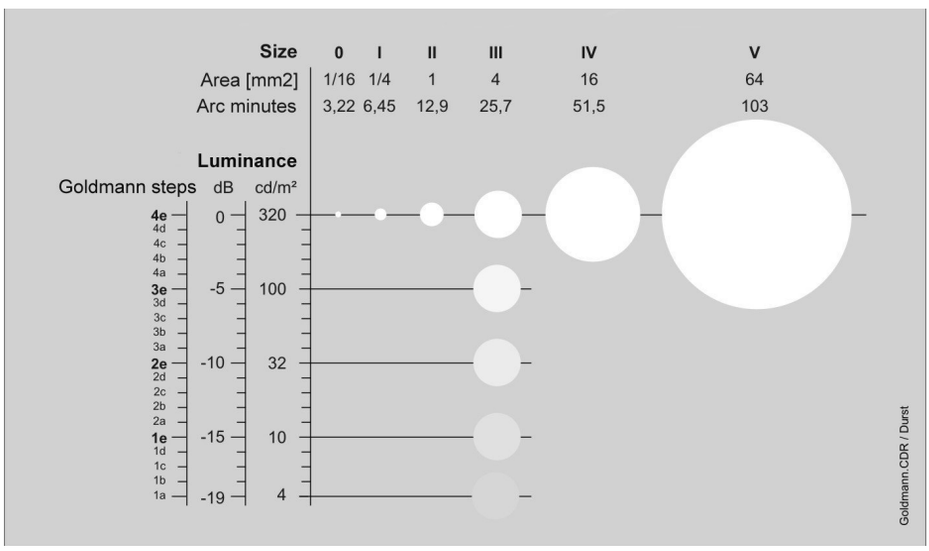



Figure 11, Goldmann Test Points

## 3.2. Test Patterns in Static Perimetry

Large, absolute visual field defects, such as hemianopsia or a quadrant defect, are usually easy to diagnose; they can even be found by finger perimetry. By contrast, small, local defects are much more difficult to detect. This is where test pattern choice becomes decisively important, since the distribution of test points across the visual field determines what defects have a chance of being detected. Using a denser test pattern increase the probability to detect a small defect. On the other hand, the greater the number of test points, the more time is required for the examination. Long examination times are not only strenuous for the patient, they also indirectly affect measurement quality. The patient's concentration diminishes over time, and the retina additionally becomes subject to neurological fatigue. For this reason the accuracy, reliability and reproducibility of visual field test results all decrease the longer the examination takes.

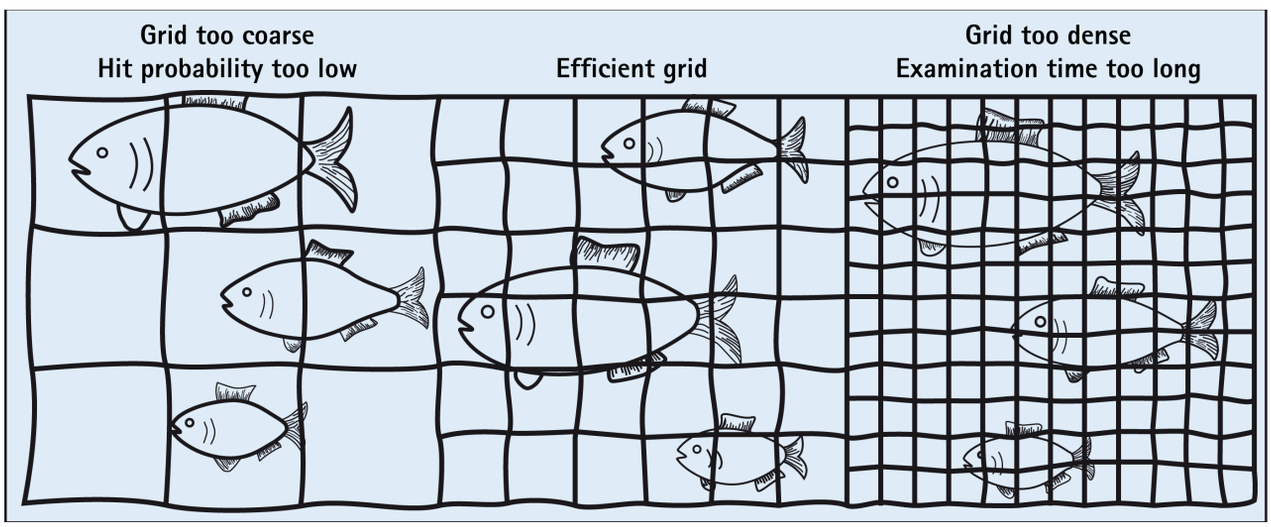



Figure 12, The Goldmann standard for perimeters

Beside their number, the arrangement of the test points across the visual field also plays an important role. For example, it is always very helpful, and in fact necessary, to find the physiological blind spot. Its location serves as a reference point (reference scotoma) in assessing the results of a visual field test. It is usually located temporally at ca. 15° eccentricity and 5° to 6° in diameter, with ca. 2/3 of its area below and 1/3 above the horizontal principal meridian.

In clinical practice one encounters various defect types which respect the horizontal or vertical meridian, meaning the 0° and 90° axes of the visual field. In order to better find the edges of such defects it is advisable to avoid placing test points precisely on any of the axes. On the other hand it is useful to have test points arranged close to the principal axes, as this makes significant differences between the quadrants more easily detectable.

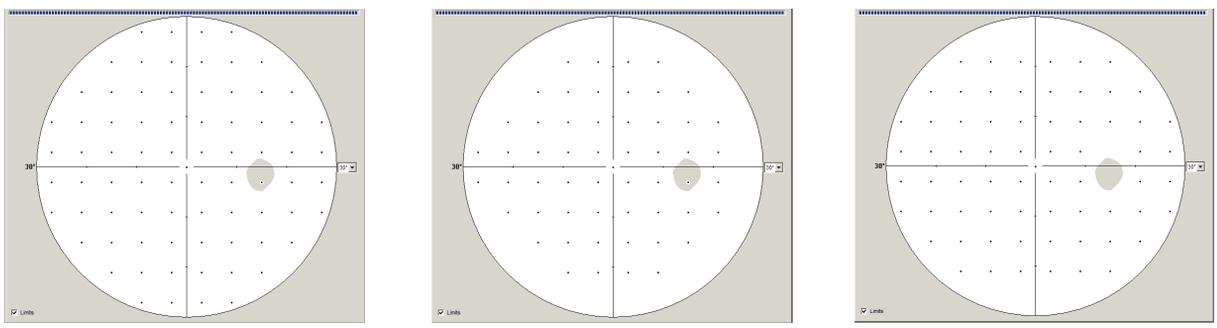
In designing a test pattern it makes sense using the physiology of the retina as reference when designing a test pattern - as typically small visual field defects are found close to the line of sight, while larger ones occur usually in the periphery. In a physiologically designed test pattern the test points will therefore tend to be more densely arranged toward the centre, giving a higher probability of finding small scotomas than if they were evenly distributed.

## 3.3. Test Patterns in OCULUS Perimeters

Which test patterns can be used on a given OCULUS perimeter is determined, on the one hand, by the particular light projection method implemented in the model and on the other, of course, the model's physical specifications.

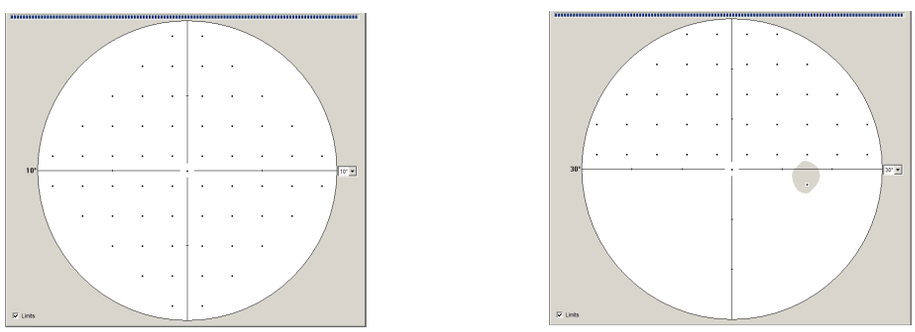
### 3.3.1. Test Patterns of the OCULUS Easyfield®

A fixed grid of LEDs covering up to 30° eccentricity is sufficient for creating the standard central 30-2 pattern or any subset of its test points. Commonly used test patterns include the standard 24-2 pattern, the pattern that covers only the upper half of the visual field and the standard 10-2 pattern, which is designed specifically for examination of the macular area.



(a) (b) (c)

Figure 13, Test patterns of the Easyfield® for examination of the central visual field: 30-2 (a), 24-2 (b) and 30x24 (c) – the latter is used for the SPARK Strategy

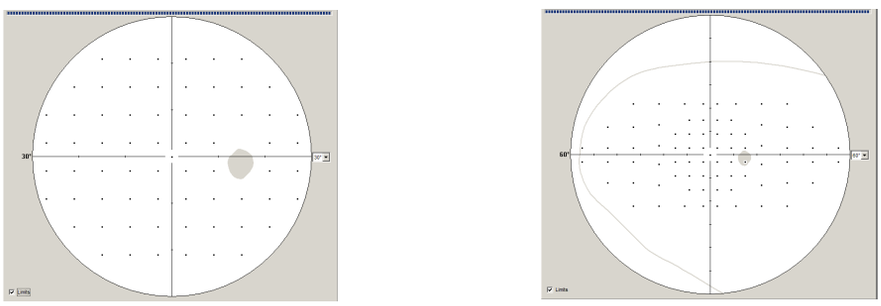


(a) (b)

Figure 14, Test patterns of the Easyfield® for the macula (a) and the upper half of the visual field (b)

### 3.3.2. Test Patterns of the OCULUS Smartfield

The Smartfield perimeter presents its test stimuli on an LCD display. This means that there is no limit to the area it can test in the examinee's visual field. Generally the Smartfield should be used with the 30x24 test pattern designed for the SPARK Strategy, but its built-in fixation shift also permits measurements of the pheriphery (Figure 15, Test patterns of the Smartfield: 30x24 test pattern for the SPARK Strategy (a) and symmetrical peripheral test pattern (b)). The regions required for examination of the macula can, of course, be just as easily screened using any of the other OCULUS perimeters.



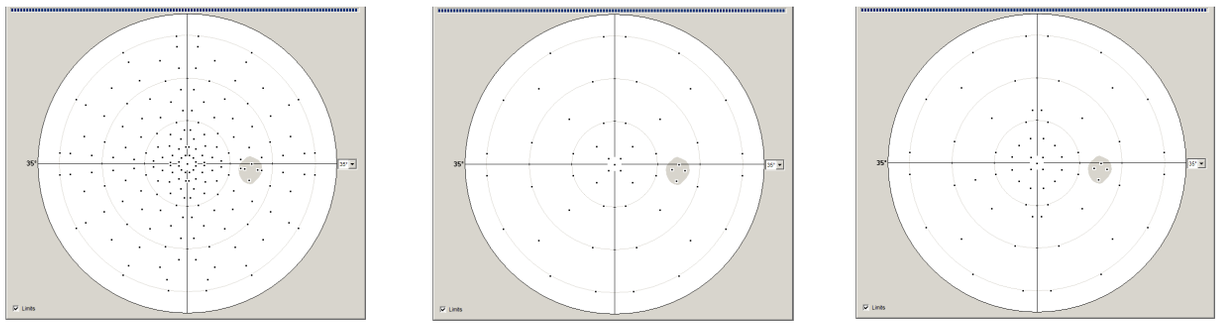
(a) (b)

Figure 15, Test patterns of the Smartfield: 30x24 test pattern for the SPARK Strategy (a) and symmetrical peripheral test pattern (b)

### 3.3.3. Test Patterns of the OCULUS Centerfield®

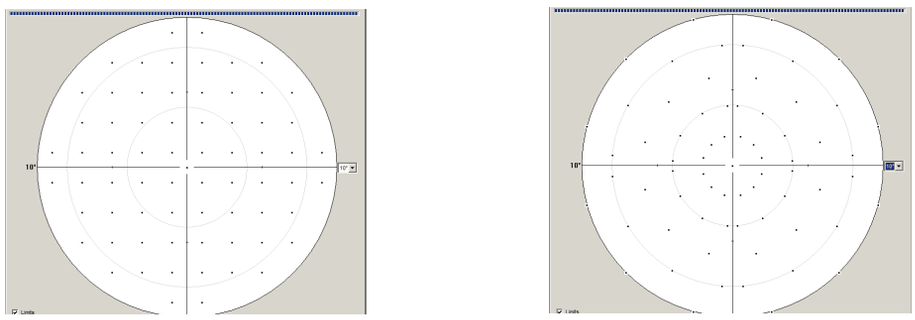
The back surface projection method enables the OCULUS Centerfield® to project stimuli in any desired location within its range up to 70° eccentricity, and it comes with a correspondingly large selection of test patterns. Moreover, it allows the examiner to define his or her own test patterns according to the needs of the individual case. In doing so the examiner can use the assistance of the test pattern editor integrated in the software.

- Central patterns: In addition to its standard selection the Centerfield® also provides test patterns with a denser arrangement of test points close to the line of sight. These patterns have been specifically designed with test points arranged according to the location and orientation of the retinal nerve fibre bundles. For this reason they are referred to as physiological test patterns. They are particularly useful in cases of glaucoma when the task is to determine the exact location of visual field defects. The central 10° range (macular tests) can be examined with the orthogonal 10-2-test pattern, but there are also alternative patterns available for this purpose.



(a) (b) (c)

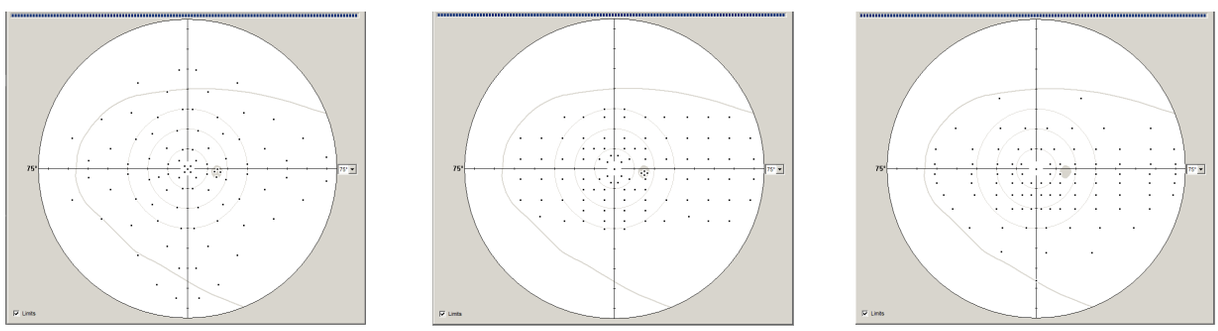
Figure 16, Physiological test patterns for examination of the central visual field with the Centerfield®: Area 1 (a) for precise location of defects, Areas 4 (b) and 8 (c) for rapid testing.



(a) (b)

Figure 17, Macula patterns of the Centerfield®: pattern 10-2 (a) and Area 3 (b)

- **Peripheral patterns:** An ingenious shift of the fixation mark allows the OCULUS Centerfield® to perform measurements of the peripheral visual field (conventionally defined as the region beyond 30° eccentricity) up to 70°. Peripheral patterns are used in particular in patients with suspected neurological pathology or in vision tests such as are routinely performed in the context of driving licence tests.

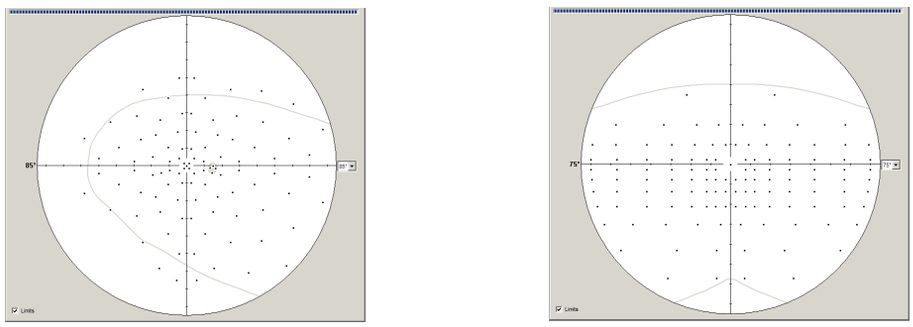


(a) (b) (c)

Figure 18, Peripheral patterns of the Centerfield®: (a) Area 6 for neurological patients, (b) pattern conforming to the requirements of the German Driving Licence Ordinance for the examination of driving licence candidates in Germany (c) pattern for the monocular Esterman test.

### 3.3.4. Test Patterns of the OCULUS Twinfield®

The most prominent feature of the OCULUS Twinfield® is its open perimetric hemisphere, which allows the entire visual field to be tested without shifting the fixation point. Its test patterns for examination of the central visual field are virtually identical to those of the Centerfield®, while those for the periphery show only slight differences, which are accounted for by the larger measuring range of the OCULUS Twinfield®. Another difference between the two models is that the Twinfield® perimeter can also be used for binocular visual field testing.



(a) (b)

Abb. 19: Periphere Raster beim Twinfield®: (a) Gebiet 6 mit leicht modifizierter Lage der Prüfpunkte und (b) Raster für den binokularen Esterman-Test.

## 3.4. Examination Strategies of Standard Automated Perimetry

There are many different ways of obtaining information on the differential luminance sensitivity (DLS) in the test locations of a test pattern. Most methods involve testing with stimuli of varying luminance at each selected location. This is done in a specific sequence based on a special algorithm which takes the patient's responses to prior stimuli into account. Measurement algorithms used in perimetry are referred to as examination strategies. Whenever we speak of strategies in the context of OCULUS perimeters we are referring to the measurement method being used .

The main objective of any strategy in perimetry is to obtain is to obtain maximum amount of information on the patient's differential luminance sensitivity using as few test repetitions per point as possible. patient's differential luminance sensitivity using as few test repetitions per test point as possible. Simultaneously obtaining accurate information on the location of the luminance threshold at each point, but also considering the patient's ability to cope with the physical and psychological stress of the perimetric examination is important. The latter factor calls for keeping the exam as short as possible. As a general rule, the higher the desired precision, the more tests per test point are required, and the longer the examination therefore take. The only notable exception to this rule occurs with the SPARK Strategy (see 3.4.1.4. SPARK Strategy).

The examination strategies available on the OCULUS perimeters can be classified into two main groups:

- Threshold strategies
- Threshold-oriented suprathreshold strategies

Since the choice of measurement strategy is solely a question of which algorithm is used, it is possible to combine any strategy with any test pattern without limitation. The only exception to this rule occurs, again, in relation to the SPARK Strategy (see 3.4.1.4. SPARK Strategy). Preferred combinations of patterns and strategies can be saved as programs for greater ease of use. Every OCULUS perimeter is

delivered with a set of preinstalled programs, which can be easily supplemented with custom programs designed according to the user's specifications.

### 3.4.1. Threshold Strategies

The goal of a threshold strategy is to determine the luminance threshold in all locations of the test pattern being used. The resulting luminance values are usually output on a perimetric decibel scale. When they have been gathered in sufficient quantity the measured sensitivity values can be subjected to statistical analysis and summarised on the basis of a small number of global statistical indices.

The physiological threshold as described in (3.1.2. Luminance Threshold) has an inherent degree of imprecision that cannot be overcome by technical means, simply because it reflects the natural fluctuation of visual field function over time that becomes apparent on repeated measurement. The best one can do to further improve accuracy is to repeat the examination several times and average the results.

#### 3.4.1.1. Full Threshold (4-2 dB Bracketing) Strategy

The Full Threshold Strategy represents the true gold standard of threshold measurement. Its underlying algorithm is easily implemented on any perimeter, and the results it generates are therefore always comparable without any trouble even if they originate from different perimeters.

The basic principles of the Full Threshold Strategy are as follows:

- All locations in the visual field are tested independently.
- All locations are tested starting from the expected sensitivity value.
- Threshold measurement is concluded after two changes in the patient's response (two crossings of the threshold).

The flowchart below shows the measurement procedure for a single location in the visual field using the Full Threshold Strategy:

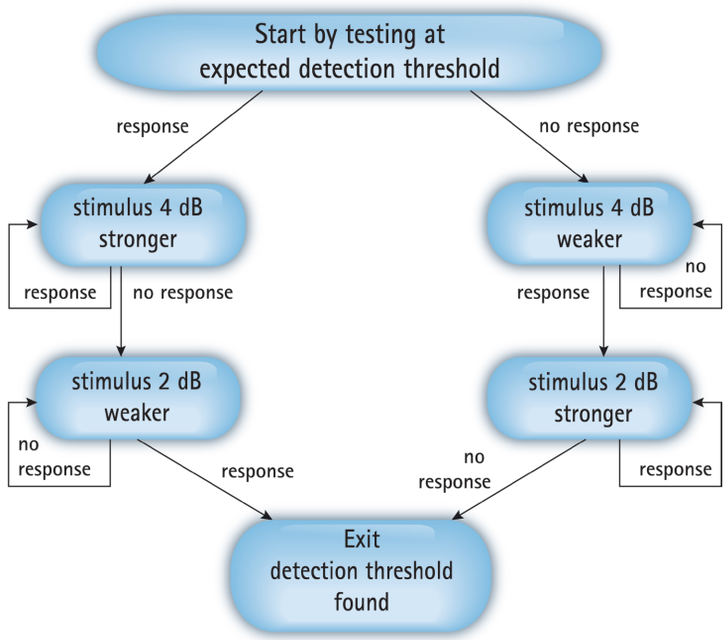



Figure 20, Full Threshold Strategy

### 3.4.1.2. OCULUS Fast Threshold Strategy

The Fast Threshold Strategy was developed with a view to reduce the long examination times associated with the Full Threshold Strategy. An obvious way to reduce examination time is to test the patient's visual field in a fewer number of test points. This leads to a loss of information, which must be compensated for in some way in some way not resulting in a loss of accuracy in a loss of accuracy. The idea of the OCULUS Fast Threshold Strategy is to achieve a compensating gain in information by starting the measurement at each test point with a luminance value equal to the expected sensitivity value at that point. This expected value is calculated on the basis of measurement results already obtained at neighbouring test points. The algorithm has been furthermore modified so as to allow regions with visual field defects to be measured more quickly. This makes sense because regions with visual field defects are often what causes examinations to last so long.

The basic principles of the Fast Threshold Strategy are as follows:

- All locations in the visual field are tested individually.
- The expected sensitivity value for a given location is calculated based on previously determined sensitivity values of neighbouring locations.
- The algorithm ensures that there is at least one crossing of the threshold.
- The threshold measurement in a given location is concluded as soon as the difference between the upper and lower limit of the sought-for threshold value drops below a defined value (3 dB).

The flowchart below shows the measurement procedure for a single location in the visual field using the Fast Threshold Strategy.

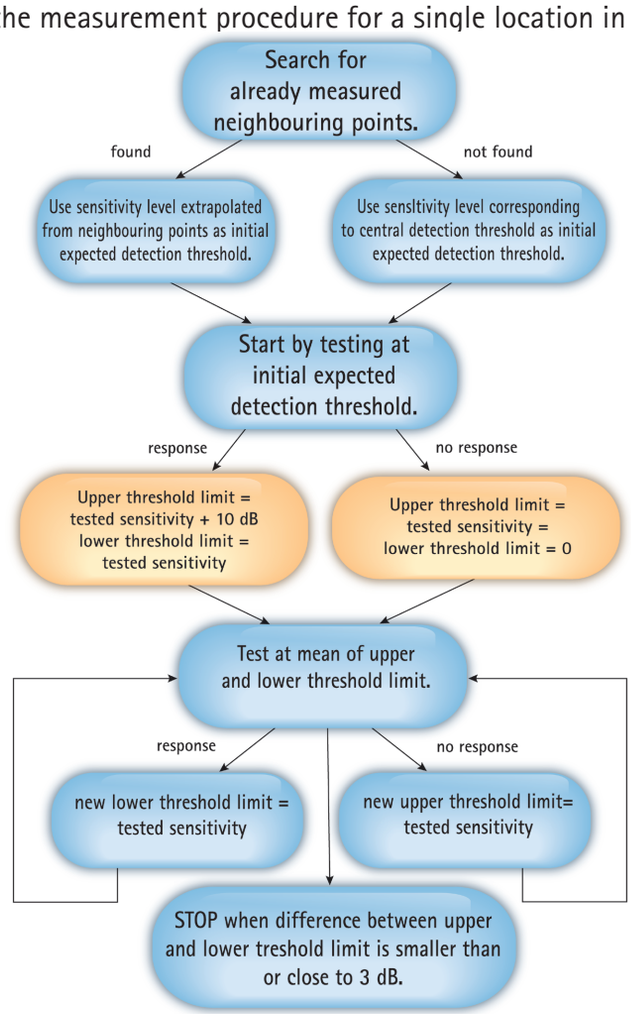



Figure 21, Threshold Strategy

### 3.4.1.3. CLIP Strategy

The CLIP (Continuous Light Increment Perimetry) Strategy is based on an entirely different examination method. Each test point in the test pattern is sampled individually. This is done by keeping it switched on and increasing its luminance in steps of 8x1 dB, 3x2 dB or nx4 dB until it is detected by the patient.

The basic principles of the CLIP Strategy are as follows:

- All locations in the visual field are tested individually.
- Stimulus luminance is increased in steps at a rate determined by the patient's previously measured reaction time.
- The algorithm requires a single crossing of the threshold.
- The threshold measurement is concluded as soon as the patients detects the stimulus (or when the maximum luminance level has been reached).

In order to further improve measurement accuracy two test points per quadrant are presampled, and the results are used as a basis for calculating suitable starting values for the other test points. With this strategy the patient's individual reaction time plays an important role. The faster the patient reacts, the faster one can increase the brightness level and the shorter the examination takes. Measurements which yield results outside the expected range can be repeated automatically.

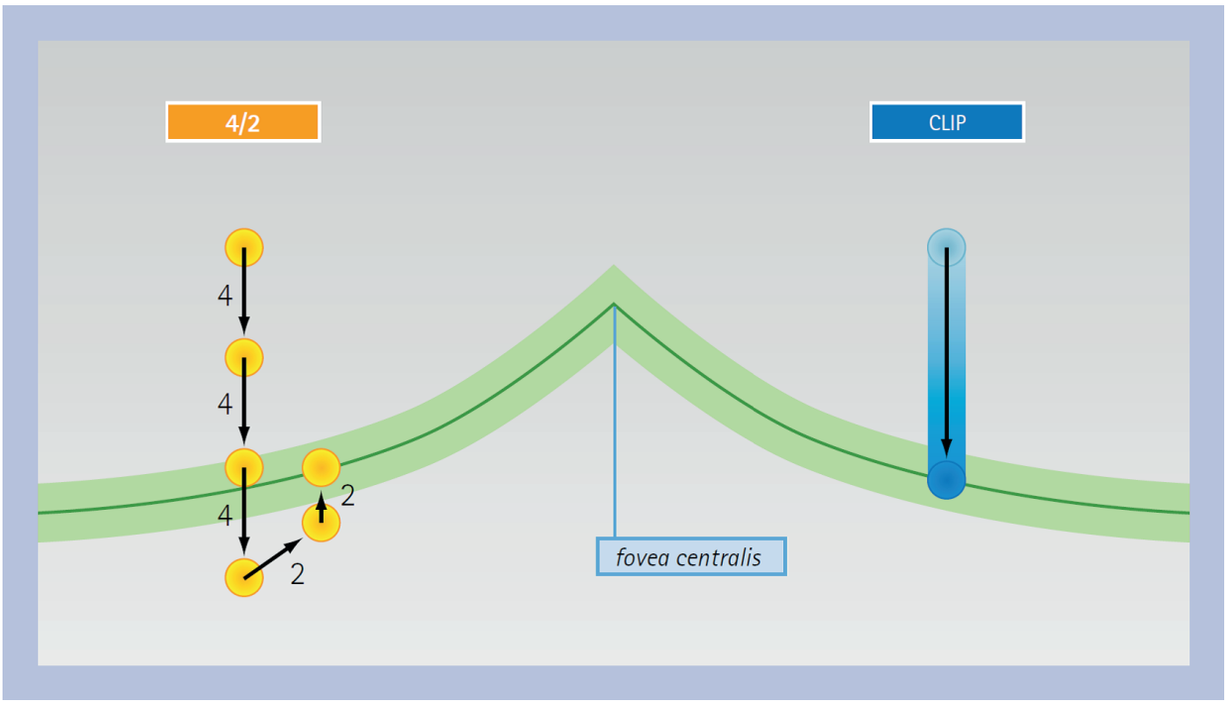



Figure 22, Illustration of the difference between the 4-2 dB bracketing strategy (= Full Threshold Strategy) and the CLIP Strategy

#### 3.4.1.4. SPARK Strategy

SPARK is the fastest of all currently known visual field testing strategies, and the results it generates are better reproducible than those of any other. This 21st century product takes advantage of all the knowledge and experience that have accumulated since the advent of computer controlled automated static perimetry. It is the product of many years of research dedicated to obtaining reliable averaged results within the shortest possible time.

The basic principles of the SPARK Strategy are as follows:

- Sensitivity thresholds are of a statistical nature. "True" visual field results can only be obtained by averaging.
- Glaucomatous defects in a visual field do not occur independently from one another. Impaired sensitivity in one region justifies the expectation that neighbouring regions are similarly impaired. Strong correlations are also found between measurement results obtained along the course of individual nerve fibre bundles.
- Average sensitivity along a given nerve fibre bundle can be approximated by an appropriate selection of test points along its course.
- Visual field locations are not tested independently from one another but rather with consideration to correlations derived from clinical studies involving large numbers of glaucoma patients.

One of the main characteristics of the SPARK Strategy is that the examination is performed in four phases. Each of these phases supplies an independent measurement of the functioning of the entire visual field, and the final result is obtained by averaging those of each phase.

##### 3.4.1.4.1. Understanding SPARK

The SPARK Strategy is based on statistical relationships between luminance threshold values representing different locations in the visual field. These statistical relationships have been derived from analyses on the results of more than 90,000 visual field examinations. Therefore a simple flowchart is not adequate for describing the algorithm applied at a given test point. Thanks to its modular design the SPARK Strategy can be used in a versatile manner in clinical practice.

During the first phase the first phase a number of preliminary tests are performed to detect any deep defects. Next, a number of representative test points are sampled along the course of various nerve fibre bundles. Based on statistical distributions derived from clinical studies the responses obtained up to that point are used to calculate threshold values expected in that particular patient. This procedure is repeated several times in order to eliminate artefacts and obtain the final threshold values to be used. The threshold values for all the remaining test points are determined by multiple linear regression analysis based on the above-mentioned clinical data. This first phase of the examination allows visual field defects to be detected within 40 seconds. It also serves to make the patient familiar with the procedure. Beyond this it can be used for screening tests on large numbers of test persons or for routine testing or persons without any known risks of disease.

The first phase, also referred to as the screening phase, can be followed up with three further examination phases for determining the topography of defects found and performing more detailed measurements. All remaining test points are included in these additional examination phases and are initially sampled at their expected threshold values. These values are then adjusted upward or downward depending on the patient's responses and with due consideration to the statistical standard

error inherent to the procedure. Threshold values for test points not directly covered in a specific examination phase are determined by interpolation. Each examination phase is concluded with a recalculation of all threshold values. After completion of all four phases each test point is assigned a final threshold value which is calculated as the median of the previously determined threshold values at that point. This procedure further improves the reproducibility of the final results because the threshold values from which the median is determined are themselves averages.

The SPARK Strategy is fine-tuned for use in screening for glaucoma as well as for clinical examination of glaucoma patients. A special version, designated SPARK-N, has furthermore been developed for use in patients with suspected neurological disease. While the two versions are similarly accurate in their ability to detect loss of sensitivity, they are more accurate in mapping the topography of such defects when they are used selectively according to their designated purpose. The fourth phase of SPARK-N involves no further measurements but rather an adaptation of the results based on calculations on the information acquired in the preceding phases.

#### 3.4.1.4.2. Working With SPARK

While OCULUS perimeter models are equipped with different versions of the SPARK Strategy, they all have the same pattern of 30x24 test points (see 3.3. Test Patterns in OCULUS Perimeters). Unlike other perimetric strategies, SPARK only works with this one test pattern. With the exception of the fixation checking method, the other examination parameters likewise allow no alternative options. In this way it is ensured that SPARK examinations are always performed under identical conditions.

The following SPARK versions are available in the operator software of the OCULUS perimeters:

- **SPARK Precision** – provides all four phases of the SPARK Strategy and yields the most accurate and the best reproducible results. SPARK Precision delivers highly accurate results in a surprisingly short time. Even a full-scale measurement procedure takes no longer than 3 minutes. SPARK Precision is recommended for clinical examinations, studies and follow-up examinations.
- **SPARK Quick** – comprised the first two phases of SPARK, for which it requires 1.5 minutes. This version is recommended for screening. In patients with prior experience in perimetry the results obtained are very similar to those generated with SPARK Precision.
- **SPARK Training** – provides only the first phase of SPARK. Due to its short duration of only 40 seconds this version is suitable for familiarising patients with the procedure, but also for screening purposes.
- **SPARK-N Precision, SPARK-N Quick** and **SPARK-N Training** have all been specifically designed to meet the requirements in cases of neurological disease. On the whole these versions are very similar to the other SPARK versions.

### 3.4.2. Threshold-Oriented Suprathreshold Strategies

Suprathreshold strategies consist in presenting a stimulus at every designated test point at a luminance level above the expected detection threshold. What sensitivity level to expect is usually inferred from the age-dependent average value for the whole population for each particular test point. This type of strategy is much more agreeable to most patients because the stimuli are brighter than with threshold strategies. Examinations based on suprathreshold strategies also require less time, since every test point only needs to be sampled once in healthy patients. Because they can be run faster, these examinations can also be performed with denser test patterns, giving a higher probability of finding local scotomas in the central visual field.

#### 3.4.2.1. Suprathreshold 2-Zone Strategy

This is the simplest and fastest of all OCULUS suprathreshold strategies. All locations of the chosen test pattern are classified into one of the two categories "seen" (normal) and "not seen" (loss of sensitivity). This makes it possible to quickly locate suspicious points in the visual field. It is not possible to distinguish defects of different depth with this strategy.

The flowchart below describes the sampling of a given test point in the visual field using the Suprathreshold 2-Zone Strategy.

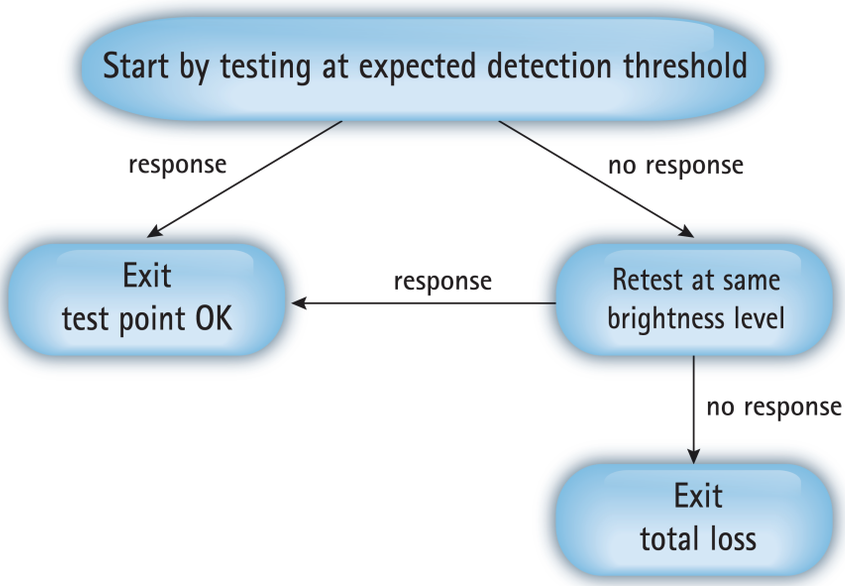



Figure 23, Suprathreshold 2-Zone Strategy

### 3.4.2.2. Suprathreshold 3-Zone Strategy

This strategy is very similar to the 2-Zone Strategy, with the significant improvement that it can differentiate between relative and absolute defects in the visual field. In this way it provides a more detailed and richer description of visual field function.

The flowchart below describes the sampling of a given test point in the visual field using the Suprathreshold 3-Zone Strategy.

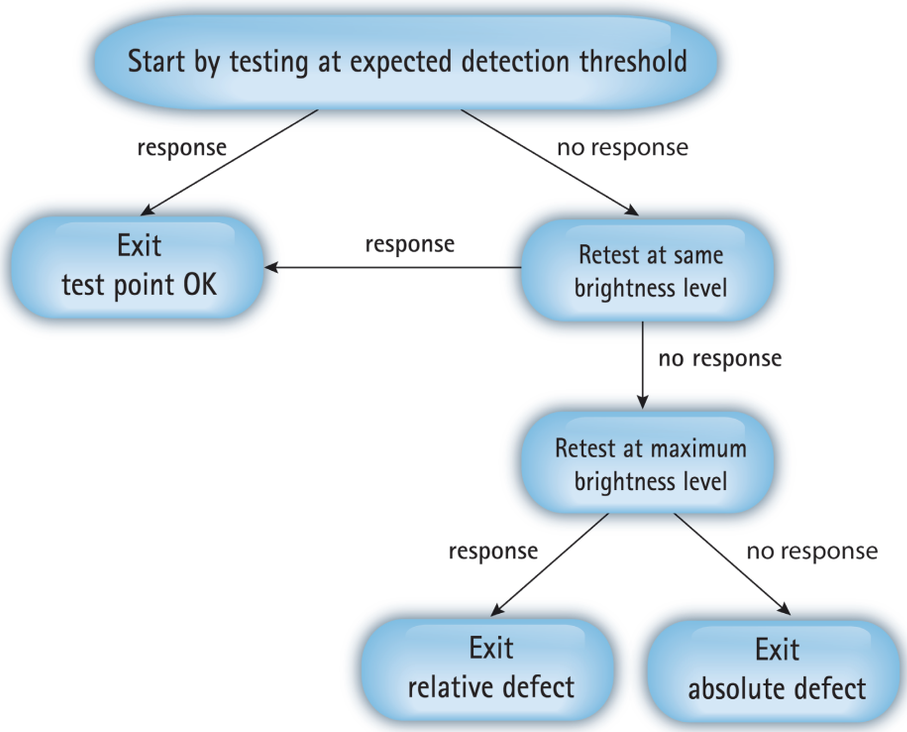



Figure 24, Suprathreshold 3-Zone Strategy

### 3.4.2.3. Suprathreshold Quantify Defects Strategy

This strategy involves a similar procedure to that of the 3-Zone Strategy, with the difference that relative defects are not only classified as such but are examined more closely for their luminance threshold using the 4-2 dB bracketing strategy. It thus combines the characteristics of suprathreshold and threshold strategies.

The flowchart below shows the procedure for measuring the visual field at a given test point using the Suprathreshold Quantify Defects Strategy:

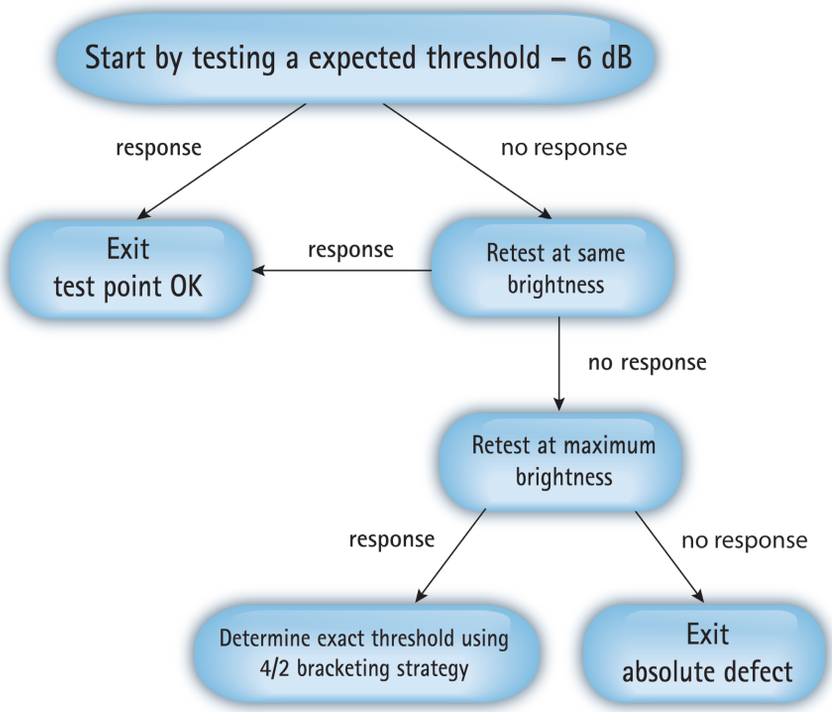



Figure 25, Suprathreshold Quantify Defects Strategy

## 3.5. OCULUS Class Strategy

(available on the Centerfield® and Twinfield®)

In examinations based on threshold-oriented suprathreshold strategies it is necessary to adapt the stimulus luminance level to the physiological decrease in differential luminance sensitivity that occurs from the centre toward the periphery of the visual field. This means that in order to remain above threshold the stimulus luminance level must increase from centre to periphery. Luminance classes define different sensitivity levels at different eccentricities as being equivalent to one another. Their gradients were determined by Aulhorn and Harms based on the average sensitivity gradients they found in persons with healthy eyes. Each luminance class is represented by a sensitivity band of approximately 4 – 5 dB width running across the eccentricity range from centre to periphery . The luminance classes are derived from age-related normative data stored in the perimeter. This explains why patient age is of interest in visual field examinations.

All OCULUS perimeters are configured with 6 contiguous luminance classes each spanning 5 dB on the luminance scale. In this way they cover the entire sensitivity range seen in clinical practice and can yet be adapted to the sensitivity level of the individual patient. Luminance class 6 ends at the instrument's maximum stimulus brightness and is used for the detection of absolute defects.

| Central luminance threshold $T_C$ | Luminance threshold $T_{15}$ at 15° eccentricity | Luminance class to be used | Symbol |
|---|---|---|---|
| 27 dB ≤ $T_C$ | 22 dB ≤ $T_{15}$ | 1 | □ |
| 22 dB ≤ $T_C$ ≤ 26 dB | 17 dB ≤ $T_{15}$ ≤ 21 dB | 2 | ◫ |
| 17 dB ≤ $T_C$ ≤ 21dB | 12 dB ≤ $T_{15}$ ≤ 16 dB | 3 | ▥ |
| 12 dB ≤ $T_C$ ≤ 16 dB | 7 dB ≤ $T_{15}$ ≤ 11 dB | 4 | ⊞ |
| 7 dB ≤ $T_C$ ≤ 11 dB | 2 dB ≤ $T_{15}$ ≤ 6 dB | 5 | ▦ |
| 0 dB ≤ $T_C$ ≤ 6 dB | 0 dB ≤ $T_{15}$ ≤ 1 dB | 6 | ■ |

Table 1: Relationship between the central luminance threshold ($T_C$) and the luminance threshold at 15° eccentricity ($T_{15}$) for each of the 6 luminance classes

There are two ways of starting an examination: Either a luminance class is selected directly based on already existing information, as in the case of a follow-up examination, or the patient's luminance is first determined. There are two automatic procedures available for determining the luminance class, both of which ultimately consist in determining the luminance threshold at suitable test points as accurately as possible. Which of the two should be used, depends on whether the examiner is working on the assumption of an intact macula or of macular disease. In the first case one measures the central luminance threshold directly, after which the computer automatically select the luminance class that best matches the measured value.

If a defect is anticipated in the area of the macula, it is better not to select the luminance class according to the central luminance threshold. Instead one should perform 4 threshold measurements at 15° eccentricity on the 45° and 135° meridians and select the luminance class according to the highest sensitivity found.

After selection of the luminance class the perimeter automatically runs a program that samples every test point for its differential luminance sensitivity.

First the perimeter presents a suprathreshold stimulus which luminance is defined by the currently selected luminance class and the eccentricity of the test point being sampled. If the patient responds to the stimulus, the examination is terminated for that test point and it is said to have the expected sensitivity, which in the case of luminance class 1 is the same as normal sensitivity.

If the patient does not respond to the stimulus, the perimeter tests for an absolute defect by presenting a stimulus of maximum luminance, i.e. 318 cd/m$^2$. If there is still no response, the software records an absolute defect for that test point.

If the patient does respond to a stimulus of maximum luminance, there may be a relative defect at the test point in question. In this case the examination is continued by presenting a stimulus of the same luminance as the initial one. If the patients fails to respond to this third stimulus, the perimeter proceeds to step four, which is to determine the depth of the defect and assign the defect to the corresponding luminance class.

## 3.6. Checking Fixation

The reliability of a perimetric examination hinges decisively on the patient's behaviour. Only if the patient maintains proper fixation (i.e. keeps his or her gaze on the perimeter target) is it ensured that the measured values actually reflect the sensitivity at the test point to which they are assigned. There is wide consensus among professionals that the most effective and reliable way to monitor the patient's fixation is by the examiner's own observation and that this should not be blindly left to some automated procedure (such as eyetracking). OCULUS perimeters are all equipped with a digital camera through which a continuous video of the eye under examination can be displayed on the computer screen in real-time, enabling the examiner to monitor the patient's gaze without interruption. The patient's fixation during the examination can additionally be monitored in one of the following two ways:

1. Checking central fixation (monitoring fixation based on the central luminance threshold): This method makes use of the fact that the sensitivity of the visual field is highest in the line of sight (in the centre) and that it drops off rapidly with growing eccentricity. After determining the central luminance threshold at the start of the examination a stimulus slightly above threshold is presented to the patient from time to time. This stimulus can only be seen with proper fixation. This method is generally recommended for use with glaucoma patients because the central field of view usually remains unimpaired for a long time after the first manifestation of the disease.[5]
2. Heijl-Krakau method (checking fixation by means of the physiological blind spot): This method consists in first determining the position of the blind spot (located on average at 15° eccentricity with ca. 80% of its area in the inferior hemisphere and subtending an angle of ca. 5°) and then presenting a bright stimulus at this exact location from time to time. Here it will not be seen if the patient's gaze is directed at the fixation target. This method is well suited for patients with an impaired macula (for whom the method of checking central fixation would not work), but not for glaucoma patients, who often show significant loss of sensitivity in the vicinity of the blind spot and might therefore not see the control stimulus even if their gaze had strayed from the fixation mark [6]. However this method of checking fixation likewise presupposes that the patient is capable of central fixation, since otherwise the blind spot might not be at the location

5 Correct fixation is indicated by the patient reporting that he or she can see the central stimulus. Since the brightness of the stimulus is above threshold, failure to see it constitutes a false-negative response. Checking central fixation is not a reliable method of monitoring fixation in patients with visual field impairment in the macular area.

6 With this method, correct fixation is indicated by the patient not responding to the stimulus. In patients with a propensity to giving false positive responses this method can make fixation loss appear more frequent than it actually is.

indicated by the measurements and its true location might not be determinable with sufficient accuracy with the test pattern being used .

## 3.7. Kinetic Perimetry

The preferred method of examining the visual field in clinical practice is by standard automated perimetry . In some situations, however, kinetic perimetry can contribute to a more accurate diagnosis.

Kinetic perimetry can be used to determine the outer boundary of the visual field as well as to measure the visual field in its entirety. One of its applications is the detailed analysis of scotomas, for example.

Kinetic perimetry involves switching on a stimulus of defined size and luminance, and slowly moving it from outside into the visual field and towards its centre. The patient is instructed to press a response button as soon as he or she sees the stimulus. This procedure is repeated with the stimulus moving inward from (normally 12) different directions. The result can be represented by joining the points which the patient first detected a stimulus of defined size and luminance to a ring. This ring is termed an isopter, which means a line of constant sensitivity.

Then the luminance or the size of the stimulus is reduced and the procedure is repeated. In this way one obtains an isopter that comes to lie further inward towards the centre. The final outcome is represented by four to five isopters describing the sensitivity of the visual field much like contour lines on a geographic map describe the relief of a territory. This examination is on the whole somewhat easier for the patient to negotiate, and it is therefore recommended if the patient might not be able to cope with a static visual field examination. It is particularly well suited for mapping the peripheral visual field.

Kinetic perimetry also comes in useful when the task is to analyse a scotoma in detail. In this case the stimulus is moved from within to outside the scotoma. The patient will then respond as soon as the stimulus passes beyond the scotoma and comes into his view. This allows the outer boundary of the scotoma to be determined with great accuracy.

One way to proceed is as follows: Slowly move the stimulus out of the blind region at a rate of ca. 2° per second, until the patient reacts by pressing the reponse button. The luminance level for each test run should be selected in such a way that the resulting isopters can be anticipated to be distributed across the visual field as evenly as possible. To allay a patient's fears or give them reassurance one can first run a mock test for demonstration by moving a small, bright stimulus through an unimpaired region.

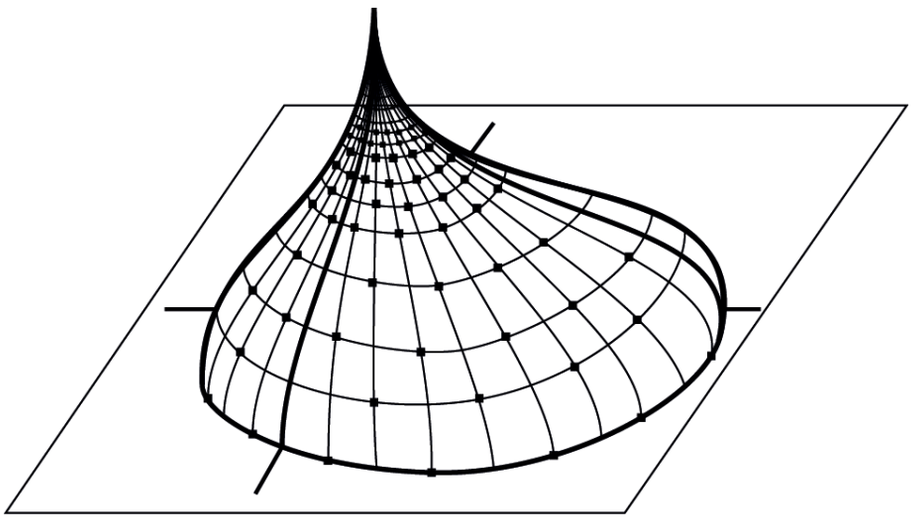


Figure 26, Geichtsfeldberg

DO NOT start with the brightest stimulus! It is always better to have a brighter stimulus in petto for the patient. Also, do not start with the weakest stimulus, since the patient may otherwise not be able to report anything.

(To determine the outer boundary of the visual field it is sufficient to determine the course of a single isopter. This is usually done using a stimulus of Goldmann size III and brightness 4e (0 dB). To obtain a more detail picture of the visual field one can then plot further isopters selected according to the needs of the case .)[7]

The OCULUS Twinfield® 2 can be regarded as a modern successor to the early mechanical kinetic perimeters in that it allows a complete kinetic visual field examination to be performed manually. By contrast, in automated kinetic perimetry a stimulus of freely selectable brightness is moved inward from the periphery along equidistant meridians. This type of examination can also be performed up to 35° eccentricity on a Centerfield® 2 perimeter using a stimulus of Goldmann size III.

However, automated kinetic perimetry only produces meaningful results to the degree that the resulting isopters are largely undistorted, i.e. that there is a more or less normal visual field. It is not suitable for mapping situations involving complex defects. This is where automated static perimetry and manual kinetic perimetry both perform superiorly and are therefore preferred.

## 3.8. Colour Perimetry

(Prof. apl. Dr. Hermann Krastel)

Diseases of the retina and optic nerve are marked by an earlier loss of sensitivity to blue and red than to white. In such cases it may be possible, in perimetry, to detect defects using blue or red stimuli that could not yet be revealed with white stimuli.

Blue Perimetry: With this method, also referred to as blue preferential perimetry (BPFP), the activity of the medium and long-wavelength sensitive cones is suppressed by yellow background illumination, allowing preferential examination of the short-wavelength sensitive system. The OCULUS Twinfield provides the option of adjusting the colours of the test point and background illumination for this

7 A commonly used sequence in kinetic perimetry is to successively plot the isopters III 4e, I 4e, I 3e, I 2e and I 1e.

purpose. Other names used internationally in reference to the method are blue-on-yellow perimetry and short wavelength automated perimetry (SWAP).

The cones and ganglion cells of the short-wavelength sensitive system ("blue cones" and "blue ganglion cells") are especially sparse in the retina, forming a conspicuously wide-meshed network. This is why BPFP is capable of detecting damage to the spatial neuronal organisation of the retina at a particularly early stage. Such damage may be found in conditions marked by macular dysfunction such as juvenile diabetes, serous maculopathy, juvenile hereditary or toxic maculopathies and retinopathies, chloroquine and hydroxychloroquine-induced maculopathy and retinopathy, Stargardt's disease and retinitis pigmentosa.

Scotomas in glaucoma patients are likewise captured more graphically by BPF perimetry than by standard white-on-white perimetry, due to the disruption of the spatial network of ganglion cells in this condition [for opticopathies, i.e. optic nerve damage, see further below]. Diabetic retinopathy is associated with receptor and ganglion cell dysfunction, but more particularly with interruption of amacrine and horizontal cells (cross-neurons). It is the latter, in conjunction with low spatial frequencies, that causes the known loss of contrast sensitivity as well as preferentially blue visual field defects.

In patients beyond the age of 45 the results of BPFP are increasingly affected by lens absorption, since the absorption of blue light by the crystalline lens increases overproportionally in older patients. This makes it difficult to distinguish whether a loss of sensitivity found by BPFP is attributable to neuroretinal damage or to increased blue absorption by the lens.

Red perimetry: Lens absorption is an especially minor issue in red perimetry. With this method red test stimuli are displayed against the same white background as in white-on-white perimetry. Another variant is red increment perimetry (RIP), which works on the same principles.

Red stimuli are well-suited for the specific examination of cone function, as rod cells are insensitive to long-wavelength stimuli. Achromatopsia, the condition of congential colour-blindness, is characterised by the more or less complete absence of cones and cone function. Patients with this disorder therefore have no or almost no visual field for the colour red.

With RIP it is possible to detect scotomas related to cone disease that would only become manifest in white-on-white perimetry at a more advanced stage. This is true, for example, for cone dystrophies, cone damage caused by hydroxychloroquine or chloroquine, carcinoma-associated retinopathy (CAR) Stargardt's disease ("pseudoprotanomaly") and age-related macular degeneration (AMD).

Medium and long-wavelength signals pass through the optic nerve at higher frequencies than do short-wavelength signals. This is why optic nerve disorders marked by slowing of nerve conduction, such as demyelination, result in visual defects that stand out particularly in red perimetry.

Conversely, primary damage to the ganglion cells, when associated with a coarsening of their spatial retinal network,  results in visual defects that stand out particularly in blue preferential perimetry.

Another point to consider is that the congenital colour vision disorders of protanopia and protanomaly are both associated with a loss of sensitivity to red and that this can manifest as a more or less pronounced constriction of the visual field under RIP. Impairment of the red visual field can be a relevant finding in the context of a medical opinion. Red perimetry examinations should therefore always be preceded by inquiring about any congenital colour vision defects and performing a colour vision test.

# 4. Practical Perimetry

Perimetry continues to be the only method of obtaining comprehensive information on a patient's visual field. Since it is a subjective examination method, its ability to generate reliable, meaningful results is crucially dependent on good patient cooperation. This chapter provides further practical advice on how to perform perimetric examinations, some of which is specific to OCULUS perimeters, while other is generally valid.

## 4.1. Program Selection

When an examiner performs a visual field test with an OCULUS perimeter the instrument runs an examination program via its software interface. The programs available for this are listed in the program list of the command software. Most program names give an indication of the kind of test that is run by the program. Nevertheless one should not attach too much importance to the program names; what matters are the program parameters. Only when the parameters available for the selected examination have been set is the examination program fully defined[1] . Most parameter settings appear on the standard printout of the examination report.

The number of examination programs that are relevant to routine practice is quite limited. The following sections offer advice on the most commonly used examination procedures available in OCULUS perimeters.

### 4.1.1. Glaucoma

Glaucoma symptoms are commonly a frequent reason to perform visual field testing. In this disease the most telling information is to be found in the central visual field up to 30° eccentricity. It is therefore advisable to start by determining the local sensitivity threshold in a few locations in this area. The table below gives parameter settings that are suitable for this purpose.

| Area | Strategy | Fixation |
|---|---|---|
| 30x24 | SPARK Precision | central |
| 24-2[bs] | Fast Threshold | central |
| 24-2[bs] | CLIP | central |

Table 2: Glaukoma Parameter[2]

In general any combination of one of the available central test patterns (24-2, 24-2bs, 30-2, 30-2bs, Area 4, Area 8) with one of the threshold strategies (Full Threshold, Fast Threshold, CLIP)[3] is suitable for an examination for glaucoma. In glaucoma patients it is advisable to check fixation by monitoring the central sensitivity threshold.

1 The following parameters can be set in the examination program of current OCULUS models: Area (test pattern), Strategy (examination strategy), Freq. (frequency of stimulus presentation), Mode (only in the Twinfield®), Standard or HiSpeed, Fixation (fixation checking method), SF (short-time fluctuation – Off, On or Auto), Stimulus (stimulus size) and Colour (stimulus colour).

2 Patterns with the supplement designation "bs" contain additional test points at the expected location of the blind spot to allow its position to be determined more accurately.

3 SPARK is exceptional in that the SPARK Precision Strategy is only possible in combination with the 30x24 pattern.

### 4.1.2. Macular Diseases

In macular diseases (such as age-related macular degeneration – AMD) it is advisable to perform a visual field test in the area around the fovea. The table below gives parameter settings that are suitable for this purpose:

| Area | Strategy | Fixation |
|---|---|---|
| 10-2 | Fast Threshold | Heijl-Krakau |
| 10-2 | Full Threshold | Heijl-Krakau |
| Area 3 | Fast Threshold | Heijl-Krakau |

Table 3: Macular disease Parameter

Whether there is macular disease, or what stage it has reached, can be determined using any combination of one of the test patterns available for this purpose (10-2, Area 3) and a threshold strategy (Full Threshold, Fast Threshold, CLIP) suited for that pattern .

Since this disease specifically affects the centre of the visual field, it is here advisable to check fixation by monitoring the position of the blind spot according to the Heijl-Krakau method.

### 4.1.3. Neurology

In neurological cases one should first decide whether it is sufficient to obtain information on the central visual field or whether information on the periphery is also needed. In the first case one should use a symmetrical pattern covering the central 30°, while in the second it is advisable to use a test pattern extending into the periphery. Since neurological diseases are usually associated with very marked visual field defects, it is justified to use a suprathreshold strategy for speed. A particularly suitable approach with neurological patients is to examine the central 30° by static perimetry and record 2 isopters kinetically using stimuli III4 and I4. The following table summarises the recommendations for neurological cases:

| Area | Strategy | Fixation |
|---|---|---|
| 30-2[bs] | 2-Zone | central |
| Area 6 | 2-Zone | central |
| 30x24 | SPARK-N Precision | central |

Table 4: Neurology Parameter

SPARK-N Precision is a modified version of SPARK Precision Strategy designed specifically for neurological cases. However, other approaches such as a combination of one of the test patterns 30-2, 30-2bs or those for Area 4, Area 8, Area 6, the Esterman test or the FeV-70 pattern (for driving licence purposes) with a 2 or 3-zone suprathreshold strategy may also be suitable for obtaining meaningful results here. Kinetic perimetry is another option in neurological cases because of its speed and greater comfort for the patient, all the more so, as static perimetry is often unreasonably stressful for this patient group.

### 4.1.4. Visual Field Screening

Screening examinations can be performed with a variety of program structures depending on whether they are general examinations or intended to detect a specific disease (such as glaucoma). Since speed is always essential in screening examinations, it makes sense to opt for a suprathreshold strategy here. This significant requirement is reflected in the recommendations below:

| Area | Strategy | Fixation |
|---|---|---|
| 24-2[bs] | 2-Zonen | central |
| 30x24 | SPARK Quick | central |
| 30-2[bs] | 3-Zonen | central |

Table 5: Screening Parameter

Generally speaking, the most likely choice for a screening examination for the visual field is to combine one of the available test patterns (24-2, 24-2bs, 30-2, 30-2bs, Area 4, Area 8) with a suprathreshold strategy (2-Zone, 3-Zone). For a very quick overview one can also use the SPARK Training Strategy with a 30x24 pattern. On the Centerfield® and the Twinfield® it is also possible to include the periphery in a static screening examination (using a test pattern for the Esterman test or Area 5 or 6 in combination with a suprathreshold strategy). The Twinfield® perimeter provides the additional option of a binocular test (which is a required part of driver aptitude tests in some countries) as well as combinations between the modules for static and kinetic screening (for example, as when the central visual field is examined by static and the periphery by kinetic perimetry for greater speed).

## 4.2. Additional Criteria

Together with the above recommendations the examination programs preset in the OCULUS perimeters provide a good starting point for putting together a suitable repertoire of examinations for all situations that may arise in the user's clinical practice. Further criteria may need to be taken into account in setting up a suitable program:

- **Compatibility:** It is often very useful to be able to compare the results of a current visual field examination with earlier perimetric findings in the same patient. This is not a trivial task, because it will often involve measurements taken with different perimeters. To provide the highest possible degree of comparability one can adapt the parameters of the current examination in advance as closely as possible to those of the earlier examinations .
- **Condition of the patient:** Some patients might have a hard time enduring an examination program of the extent that would be required for them, while for other patients some parts of an examination may have become irrelevant . Very often one can significantly improve both the quality and the meaningfulness of perimetric findings by reducing the duration of the examination. This can be done by reducing the number of test points, switching from a threshold to a suprathreshold stategy or by adapting the test pattern to the topology of the presenting visual field defects.
- **Special considerations:** Sometimes the standard examination programs may not be sufficient for obtaining clear-cut results. In such cases an experienced examiner may be able to use a custom-designed progam to resolve whatever remaining questions there are. Besides this, custom-designed programs can also be valuable for research purposes.

## 4.3. Reliability of the Examination

The results of a visual field examination not only supply location-specific information on the patient's luminance sensitivity, they are often also needed for backing up therapeutic decisions. Therefore it is essential to be able to assess the reliability of results obtained from an examination. One basic prerequisite for this is of course a properly functioning perimeter. Due to the subjective nature of perimetric examinations, however, it is also indispensable to have a means of assessing the patient's behaviour during the examination. Among the examiner's responsibilities are monitoring the patient, instructing them that they are being observed, motivating them and allowing them a pause when they show signs of strain or fatigue. Such signs include frequent changes in sitting posture or carriage of the head or an elevated blink rate.

Aside from the different possibilities of interaction between the examiner and the patient, which can hardly be replaced by technical means, most perimeters are equipped with tests for monitoring data quality. These may be based on any one of the following three main indices:

1. **Checking fixation:** This indicator measures the quality of the patient's fixation. OCULUS perimeters are equipped with two optional measurement methods for this purpose (see 3.6. Checking Fixation):
    a. **Checking central fixation** (checking fixation based on the central luminance threshold): This method makes use of the fact that luminance sensitivity drops off rapidly temporally from the fovea (within an angle range of ca. 2°). A stimulus presented in the patient's line of sight at a brightness level just above the foveal sensitivity threshold will only be seen if the patient's gaze is not significantly  off target. Failure to respond to this fixation catch-trial constitutes a false-negative response.
    b. **The Heijl-Krakau method** (checking fixation by means of the physiological blind spot): This makes use of the blind spot as a reference location at which no stimulus should be seen. Since the blind spot covers a larger area than does the fovea, this method is only capable of detecting fairly large deviations from the fixation target. This method loses meaningfulness particularly in cases where the blind spot itself is affected (as in severe glaucoma, for example), whereas it can be recommended in the case of visual field defects in the macular area. With the Heijl-Krakau method it constitutes a false-positive response when a patient reports seeing the stimulus.
2. **False-positive rate:** This index measures a patient's tendency to give a positive response when no stimulus has been presented. In OCULUS perimeters the false-positive rate is determined by having the instrument make all the noises and movements normally associated with a measurement, but without presenting a stimulus, and then determining the patient's reaction to this. This method makes it possible to identify "happy trigger" patients. If it goes undected, a high false-positive rate will normally produce misleading results which make the patient's visual field function appear better than it actually is. If this is discovered, the patient should be instructed to give positive response only when they really see a stimulus and then repeat the false measurements.

3. **False-negative rate:** This index measures a patient's tendency to ignore a stimulus which he should actually be able to see, having responded to the same stimulus only a moment ago. However, supposed false-negative responses may also be due to strong fluctuations in visual field function, which occur frequently in glaucoma.
4. **Short-Term fluctuation (SF):** This index is used for estimating the reliability of threshold measurement based on repeated measurements at each of several different locations. It should be taken into consideration that repeated threshold measurements are associated with longer examination times - hence greater error probability. Furthermore, in an impaired visual field the index's significance is diminished from the outset, since impaired regions of the visual field show an elevated variability of function quite independent of examination quality. This index is no longer used with modern strategies such as SPARK, which put priority on reducing examination time as a means of avoiding measurement errors. Nevertheless, the SF index may still be a justified option for testing reliability when the CLIP Strategy is used in patients with incipient visual field loss due to glaucoma.

When performing threshold measurements of the central visual field the results of the above catch trials are used to calculate a Reliability Factor (RF), which may range anywhere from 0 to 1. A rule of thumb says that RF < 0.7 points to an unreliable result. If RF > 0.85, the result will normally be reliable, while in the range 0.7 < RF < 0.85 it will certainly be advisable to review the individual reliability indices.

In the event of unreliable results the examination should be repeated. However, there may be situations where a repeat examination is unlikely to improve validity (such as when there are marked defects near the fovea, a condition that usually makes fixation difficult). In such cases the examiner must attempt to estimate how the patient's impaired fixation may have influenced the result and assess the case accordingly.

## 4.4. Recommendations for Obtaining Accurate Perimetric Results

It is essential that the external conditions of an examination meet certan minimum standards if it is to yield valid and meaningful results. While the details to be observed may vary somewhat from one instrument to another, certain general rules always apply. Ensuring that the external conditions of a visual field examination meet the required standard is also essential for being able to perform meaningful follow-up examinations.

The recommendations given in the following are intended for examiners with no or little practical experience in perimetry. With growing experience the examiner will learn to adapt the settings and external conditions of a visual field examination to the givens of the individual case, including the patient's ability to cooperate.

General Recommendations

- Visual field examinations demand a high level of concentration; therefore the examiner should ensure a quiet, undisturbed environment.
- In order to obtain meaningful results it is important to explain the examination to the patient in simple words. This should include information on how fixation and response behaviour are monitored, the possibility to take a break, and the expected duration of the examination.

- Some patient need continuous motivation over the entire course of the examination, while others need calming because they are nervous or suffering from physical complaints. For this reason it is advisable to answer in advance all of the patient's questions about the examination they have been scheduled for. This will ease the examiner's work as well as improve the patient's cooperation considerably.
- The patient should be seated as comfortably as possible in front of the perimeter (with an upright sitting posture and head carriage). If their sitting comfort is even only minimally disturbed, this may become a serious source of interference within a matter of a few minutes. The patient must keep their head in the correct position and maintain their fixation on the target throughout the examination, since without proper fixation there will be no valid results.
- Usually the better eye is examined first. This will make the first examination easier for the patient, enabling them to gain confidence and relax better during the examination of the other eye. The eye not being examined should be covered with a translucent occluder , allowing the patient to keep both eyes open and in the same state of adaptation. This is irritating for some patients, in which case the eye not being examined should be covered with a dark occluder. This can lead to a slight shift in sensitivity thresholds due to dark adaptation. (The Smartfield and the Easyfield® both come with premounted translucent eye shields, permitting examinations to be performed without an occluder).
- The pupil should not be dilated prior to the visual field test, nor should any ointment or gel be applied to the eye.
- Since the pupil diameter has an effect on the outcome, but no bearing on the examination procedure, it is advisable to measure it. The influence of pupil diameter on sensitivity is greater in the central visual field than it is in the periphery. (The smaller the pupil diameter, the less light enters the eye and the lower its sensitivity becomes. In kinetic perimetry this shows up as an inward shift of the isopters). The same holds for opacities in the refracting media.
- The room illumination should be at an appropriate level. Examinations on the Smartfield, Easyfield® or Centerfield® can be performed in a normally lit room, provided the lighting is diffuse and there are no powerful light sources in the patient's back. The Twinfield® requires a darkroom, however, and its perimetric hemisphere must be free of shadows.
- When testing with a correction lens, the pupil must be centered on the lens. The position of the pupil can be monitored with the perimeter's camera function. The distance between the eye and the corrective lens should be ca. 1 cm to guard against lens edge effects being mistaken for visual field defects. Shorter distances can cause water to condense on the lens, resulting in lower measured sensitivity levels, whereas if the distance is too large, the edge of the lens can obstruct the patient's view, resulting in artefacts.

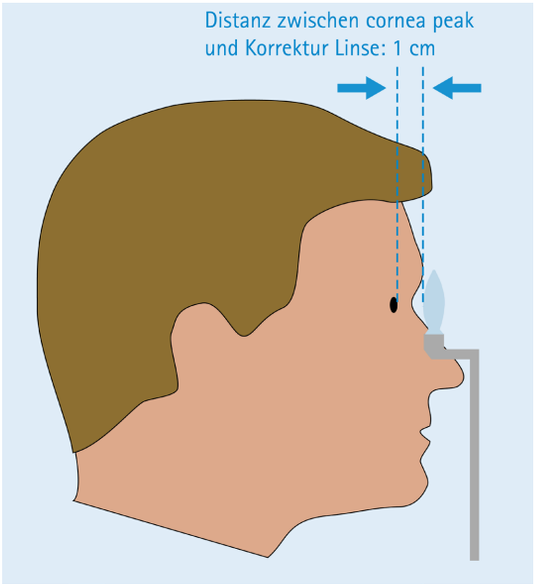



Figure 27, Proper position of a corrective lens

- The frequency of stimulus presentation (hence the speed of the examination) should be appropriate to the patient's capability. Both eyes should be examined, especially when it is the first examination.
- The examiner should determine which part of the visual field is to be examined, select a suitable strategy and insert a lens appropriate to the patient's age and accommodation.
- If the results give reason for doubt, the examination should be repeated (immediately or soon). Suspicious findings should likewise be followed up with a repeat examination. Sometimes it will be sufficient to re-examine only certain regions of the visual field.

## 4.5. Near Correction for Examinations with a Perimeter

For an accurate perimetric examination the patient must be able to see the stimulus as sharp as possible. This means that the examiner must ensure that the patient has good visual acuity at the customary testing distance of 30 cm. If there is ametropia, a suitable corrective lens should be used. Any astigmatism of more than 1.0 D should also be corrected. If the patient's near vision correction value is not known, the sought value can be roughly estimated on the basis of their far vision correction value by adding to this an age-dependent correction value as shown in the table below:

| Age | Addition |
|---|---|
| 40 Years + | +1.0 D |
| 50–60 Years | +2.0 D |
| Above 60 Years | +3.0 D |

Table 6: Correction table

There may always be deviations from this, which then need to be considered individually. For example, patients aged between 40 and 50 with latent hyperopia require stronger positive correction.

Another point to consider is that use of thick lenses can affect visual acuity, negatively influencing the the examination. Thick corrective lenses should be positioned closer to the eye, i.e. placed in one of the nearer lens holder slots , in order to avoid "lens edge scotomas" as best possible.

Spherical and cylindrical lenses can be converted as follows in order to reduce lens thickness for a given refraction:

| | | | |
|---|---|---|---|
| Example: | sph +4.0 | cyl -3.0 | A 90° |
| | sph +1.0 | cyl +3.0 | A 0° |

Add the cylindrical value to the spherical value (+4+(-3)=+1), invert the sign of the cyindrical value (-3 becomes +3) and turn the axis by 90° (90° becomes 0°). Many perimeters perform this conversion automatically in their software.

Corrective lenses should only be used for the examination of those regions of the visual field that are enclosed by the rim of the corrective lens in the test situation , i.e. up to ca. 30° eccentricity.

They are generally not required for the periphery and should only be used here if the patient would otherwise not be able to recognise the fixation target at all. If a corrective lense is kept in place while examining regions close to the edge of the lens, this can lead to findings of scotomas or a concentrically constricted visual field when in fact the sampled test locations merely happened to fall on the rim of the lens. This is also why only thin-rim corrective lenses that fit snugly into the lens holder are allowed.

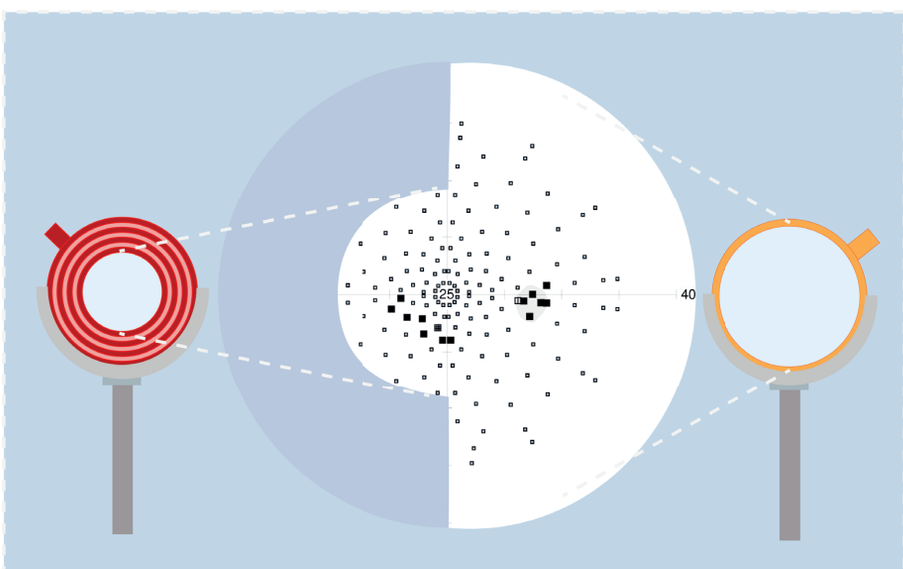



Figure 28, Illustration of the deceptive effect of a conventional test lens versus a thin-rim lens.

It is also possible to perform the examination with the patient wearing their own monofocal near-vision glasses or contact lenses or, with intact and sufficient accommodation, their own far-vision glasses.

Using a wrong corrective lens or misaligning a corrective lens can make the test points appear blurred and more difficult to identify, reducing the patient's measured differential luminance sensitivity. These effects become more apparent with smaller stimuli; they uniformly affect all parts of the visual field, leading to a homogeneous decrease in differential luminance sensitivity. Using a corrective lens

off-centre can have the additional effect of producing seeming absolute defects which can appear in any angular direction depending on the direction of misalignment, which in fact are caused by the rim of the lens.

In order to avoid lens edge artefacts and artefacts related to inadequate correction it is essential not to use any of the following

- no vari/multifocal lenses
- no bifocal or trifocal lenses
- no wide-rim frames
- no toned lenses
- no edge absorption glasses
- no half-eyes

Corrective lenses of ca. -5 D and stronger have the effect of making the image on the retina smaller and the visual field larger; the blind spot is also larger and located further outward, while the isopters in kinetic perimetry also come to lie further outward.

Positive corrective lenses of ca. + 5 D and stronger make the visual field smaller; the blind spot is also smaller and located further inward, while the isopters in kinetic perimetry come to lie closer together.

Literature: „Rasterperimetrie mit dem Tübinger Automatik Perimeter" (F. Dorner-Schandl, W. Durst, G. Kolling, B. Leo-Kottler)

# 5. Interpreting Perimetry Results

After carrying out a visual field test the examiner must interpret the results obtained. This is a complex task, since not only the measured data but also, as far as possible, the subjective aspects of the examination need to be considered (after all, one is dealing with a functional test that is subjective by nature). In order to arrive at a correct interpretation of perimetric results the patient's entire history must be taken into account. Through continued practice, and with growing years of experience, the practitioner will become incomparably more confident in interpreting the results of visual field examinations. Without laying claim to completeness, this chapter presents guidelines for the interpretation of examination results of static perimetry.

## 5.1. The Examination Printout

As a rule, one will assess the results of a visual field examination based on the information contained in the examination printout. This section describes the structure of the standard printout template using a threshold examination of the central visual field performed on an OCULUS Twinfield® perimeter as an example (see Figure 29, Example of an examination printout from a threshold examination performed with the Twinfield®)[1].

A standard printout contains information in the form of written text, numbers, symbols and/or charts. The sections numbered in Figure 29 are described in the following:

1 The standard printout can differ in appearance from one manufacturer to another, but the essential clinical information is always included and easy to find.

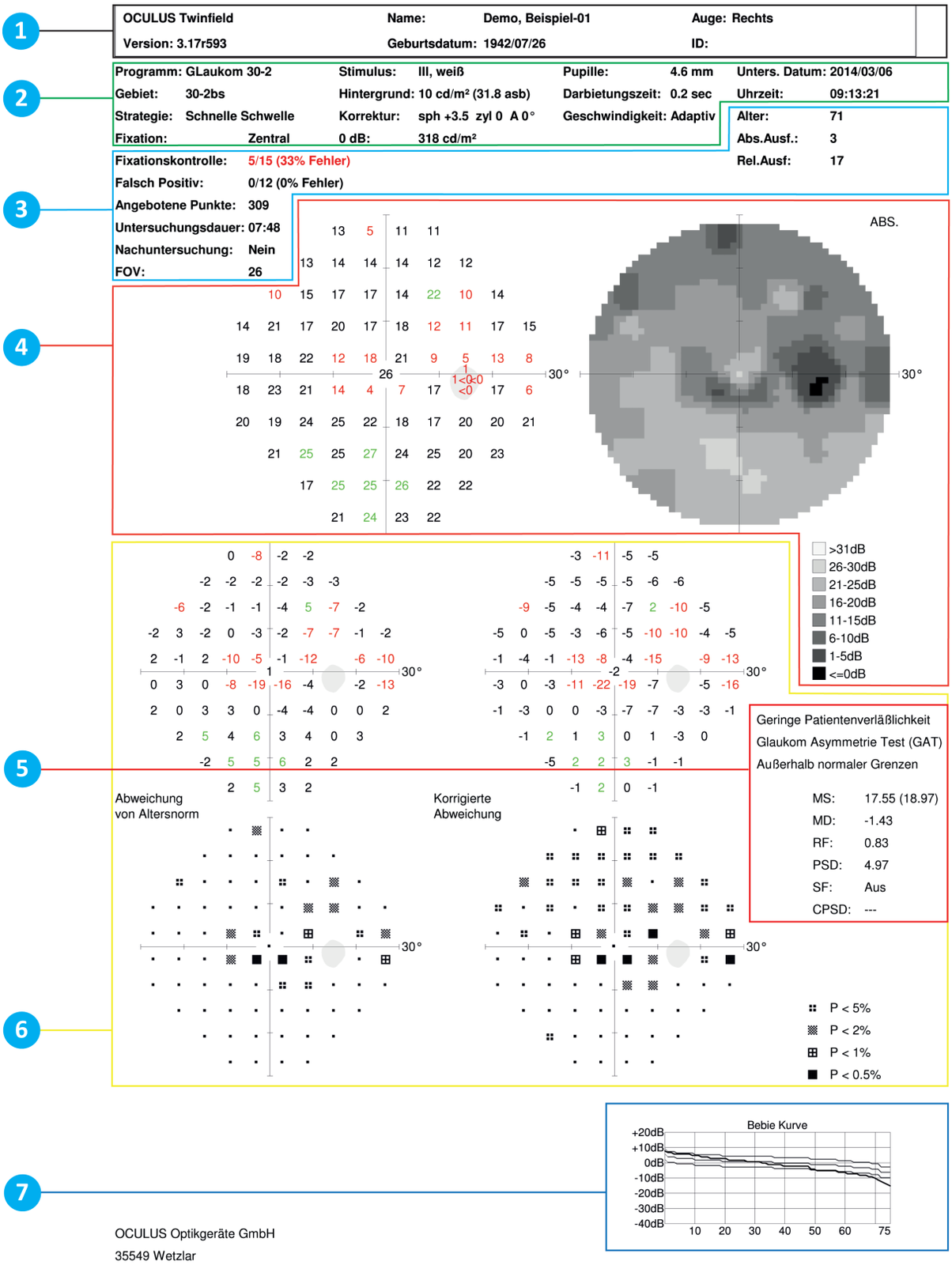



Figure 29, Example of an examination printout from a threshold examination performed with the Twinfield®

1 Patient-specific data: patient's name and date of birth, patient ID and eye under examination (left/right). The software version used for the examination is also given here.

2 Examination-specific data: information on the examination performed:

- Designation of the examination program ("Program"), test pattern ("Area"), examination strategy used ("Strategy") and method of checking fixation ("Fixation").
- Stimulus size and colour ("Stimulus"), background illumination ("Background"), refraction correction used ("Correction"), maximum stimulus luminance ("0 dB").
- Pupil diameter ("Pupil"), stimulus presentation time ("Presentation time"), examination speed ("Speed").
- Examination date ("Date of exam.") and time ("Time"), patient age ("Age").

3 "Fixation check": the results of the fixation catch trials. This is given as the number of fixation losses and the total number of fixation catch trials performed (e.g. "4/21") and the resulting percentage (e.g. "19% Losses")

- "False-positive": the results of the false-positive catch trials. This is given as the number of false-positive responses and the total number of false-positive catch trials performed (e.g. "2/23") and the resulting percentage (e.g. "9% Error")
- "Presented dots ": the total number of presentations during an examination, including those performed as catch trials
- "Duration": duration of the examination
- "Re-examination": shows whether the results were obtained in a re-examination ("Yes" or "No")
- "FOV": the value of the foveal luminance threshold (in decibels)
- "Abs. loss": the number of detected absolute defects
- "Rel. loss": the number of detected relative defects

4 Main results display: contains the map of threshold values and a greyscale map.

- Map of threshold values: shows the measured absolute threshold values at all test points of the selected test pattern; serves to assess the patient's visual field sensitivity.
- Greyscale map of threshold values: shows the measured threshold values encoded in shades of grey. With the Easyfield® the user can choose in the settings between having the absolute ("ABS.") or the relative ("REL.") threshold values displayed. The relative greyscale map is in effect a map of the total deviation (see point 6. below) and is of greater clinical significance than the absolute greyscale map. A legend of the different shades of grey is also displayed.

5 Global evaluations and perimetric indices:**Glaucoma Asymmetric Test (GAT):** The evaluations of this test are displayed when areas containing the test points of the 24-2 test pattern are used. The examiner should follow the same procedure as with the Glaucoma Hemifield Test (GHT). Comparison of the threshold values for the upper and lower hemisphere can lead to any of the following conclusions:

- abnormally high sensitivity
- within normal limits
- borderline case
- outside normal limits
- globally reduced sensitivity

Note: With the OCULUS Twinfield® and Centerfield® perimeters you can choose between Mean Deviation and Mean Defect for MD as well as between PSD (Pattern Standard Deviation) and LV (loss variance ) – see below for further explanation.

- **MS – Mean Sensitivity:** gives the arithmetic mean of the absolute sensitivity values measured with the current test pattern. The value in brackets gives the population mean for the patient's age (range ) as derived from normative studies. If the mean of the measured values is lower, this means that the patient's visual field sensitivity is diminished.
- **MD – Mean Deviation:** The mean deviation of the measured sensitivity values is equal to the difference between the patient's mean sensitivity (MS) and the age-related normal mean. The more negative this value, the poorer the patient's visual field function is. On the Twinfield® and Centerfield® the user can also choose to have MD stand for Mean Defect (depth), which is the same as the Mean Deviation with an inverted sign.
- **PSD – Pattern Standard Deviation:** gives the degree of irregularity of the measured visual field. PSD is a measure of the difference in shape of the visual field hill between the eye under examination and a normal eye. Local defects are associated with an increase in PSD. On the Twinfield® and Centerfield® the user can instead choose to have LV – Loss Variance displayed, which is a measure of the irregularity of sensitivity loss as reflected by the visual field hill .
- **RF –Reliability Factor:** This is calculated from the results of the catch trials and can take on any value between 0 and 1. The higher RF, the better the patient's cooperation was. An RF < 0.7 means that the patient's cooperation was poor and that the examination should be repeated . An RF > 0.85 normally means that the patient's cooperation was sufficient to proceed with the evaluation.
- **SF –Short-Term Fluctuation:** gives the variability of threshold measurements in the course of an examination. This index is only recorded if the corresponding option has been activated in the parameter settings for static examinations (otherwise the setting will read "off"). High SF values typically occur when a visual field has large defects, but they may also be an indication that the patient was not cooperating well.
- **CPSD – Corrected Pattern Standard Deviation:** A high PSD value may either be due to fluctuations in the patient's response behaviour or to true irregularities in the visual field. The CPSD corrects the PSD for fluctuations in patient response behaviour based on the measured short-term fluctuation (SF). If no SF value is available, then no CPSD is calculated.
- **GSS:** glaucoma stage according to Brusini's Enhanced Glaucoma Staging System (only available on the Easyfield® and Smartfield): gives the estimated stage on a scale from 0 to 5 or B (for borderline) and the type of defect (L for local, G for generalized, M for mixed).

6 Deviations from the age-related normal and corrected deviation

- Deviation from the age-related normal (= Total deviation): gives the deviations of the threshold values measured at all of the test points from those one would expect in a normal eye of a patient of the same age (top left). In the map on the bottom left the significance of these deviations is indicated by symbols representing different p-value intervals. Since luminance sensitivity is by nature more varibale in the peripheral visual field, deviations from the age-related normal must be larger here in order to be considered significant.
- Corrected deviation (= Pattern deviation): gives the deviations from the age-related normal corrected for the general height (GH) of the visual field. Correction is based on the 85th percentile of all defects found for that eye. The purpose of this correction is to eliminate from the measured defects any generalized sensitivity loss that may be due to opacities in the refracting media (as, e.g., in cataract). In patients with widespread sensitivity loss deviations thus corrected can make local defects more visible. Note that this map only carries clinically meaningful information if the correction was successful in eliminating global sensitivity loss, i.e. if the resulting losses are lower than the age-related deviations in the original map.

7 Cumulative defect curve: The defect curve (= Bebié curve) shows the age-related deviation values ranked in decreasing order. It follows from this definition that clinically normal ("healthy") locations in the visual field will appear at the beginning (on the left) while clinically remarkable ("more impaired") locations will be located more to the right on this continuously declining curve. All location-specific information is lost with this representation. Its advantage is its robustness against natural threshold fluctuations. The defect curve is shown together with a reference curve (including confidence interval curves) representing a normal visual field.

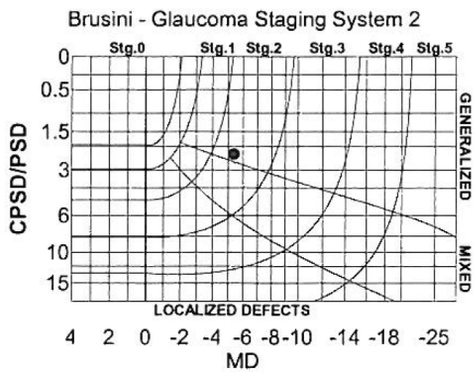



Figure 30, Brusini - Glaucoma Staging System

8 Glaucoma Staging System (GSS 2 plot): graphic representation of Brusini's Enhanced Glaucoma Staging System (only available on the Easyfield® and Smartfield). This diagram classifies the results of a visual field examination based on the Mean Deviation (MD) and the Pattern Standard Deviation (PSD or CPSD). These are represented as a point in a two-dimensional graph of these two perimetric indices. The diagram highlights different regions each marked by a specific stage (stage 0 – 5) of visual field loss or stage of disease. It also allows a distinction between generalized and local defects as well as mixed-type defects.

## 5.2. Classifying Visual Field Defects

The topology of visual field defects plays an important role in their classification. As illustrated in the previous section, visual field examination results are customarily represented from the point of view of the patient ("as the patient sees it") . The designation of the visual field quadrants follows this convention. As shown in the diagram below, the upper part of the visual field of each eye is called superior and the lower part is called inferior. The part next to the nose is referred to as nasal while the outer parts are called the temporal areas of the visual field.

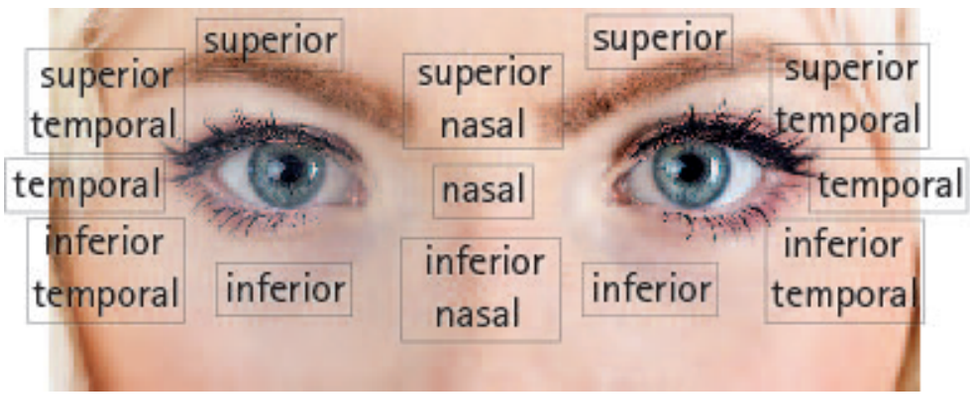



Figure 31, Field of Vision

## 5.3. A Normal/Healthy Visual Field

A normal monocular visual field extends

- ca. 60° nasally and superiorly
- ca 70° inferiorly
- ca 90 ° temporally

The visual field is the term used in the fields of physiology, ophthalmology, neurology or, speaking more broadly, perceptual research in reference to the field of view afforded by the eyes when stationary , weighted by the light sensitivity of the central nervous system in receiving and processing incoming light impulses. The visual field represents both the space (in the 2-dimensional sense) visible to a stationary eye as well as "...the entirety of visual signals that are transmitted to the cerebral cortex and perceived ."

A distinction can be drawn between the monocular visual field of either the right or the left eye and the total visual field, which is the sum of the two monocular visual fields. In humans the monocular visual fields of the two eyes overlap, and the area of overlap is referred to as the binocular visual field. This is the field in which binocular fusion is possible and which gives rise to the horopter – a prerequisite for stereoscopic vision. In adults the total visual field spans an horizontal arc of ca. 214° (ca. 107° on either side), and a vertical arc of ca. 60°–70° upward and ca. 70°–80° downward. The total visual field thus covers around one third of the entire solid angle space.

The practice of quantitative examination and quantification of visual field function is referred to as perimetry. This discipline not only plays an important role in diagnosing diseases of the visual system, but can also be part of a general neurological workup.

It is possible for the facial features, including the eyes and nose, to constrain the outer limits of the visual field.[1]

## 5.4. Origin of Visual Field Defects

A certain basic knowledge on the structure of the visual pathway is essential in oder to be able to correctly interpret representations of visual field defects on the examination printout. When light enters the eye through the refracting media it is projected onto the retina. As shown schematically in Figure 32, Schematic diagram of the visual pathway, the right side of the visual field (green) is projected onto the temporal side of the retina of the left eye and the nasal side of the retina of the right eye. The information received there is transmitted through the optic nerve to the optic chiasm and further on to the left cerebral hemisphere. The optic nerve itself can be divided into three regions: the prechiasmal region (located before the optic chiasm), the optic chiasm itself and the postchiasmal region. As shown below, the nasal nerve fibres cross over to the contralateral hemisphere, while the temporal nerve fibres change direction to project into the ipsilateral hemisphere.

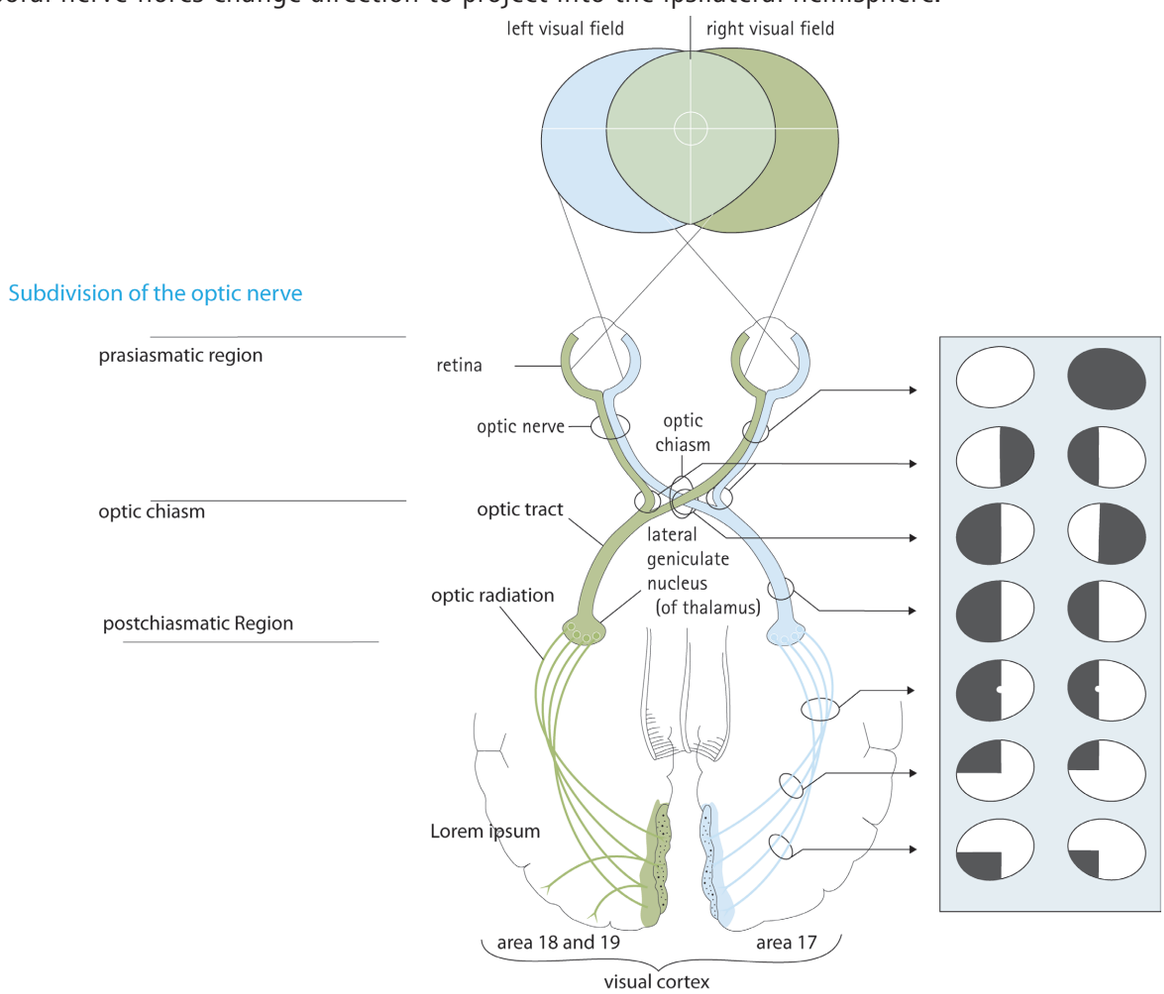



Figure 32, Schematic diagram of the visual pathway

1 Wikipedia: excerpt from German Website "Gesichtsfeld (Wahrnehmung)" translated into English by Conrad Heckmann. In: Wikipedia, Die freie Enzyklopädie; page last edited on 13 March 2017, 14:15 UTC. URL: https://de.wikipedia.org/w/index.php?title=Gesichtsfeld&oldid=155631651 (called up on 22 March 2017, 14:15 UTC)

Visual field defects can thus be classified into three groups according to their topological origin:

1. Prechiasmal lesions: These include lesions of the visual pathway between the cornea and the optic chiasm.
2. Chiasmal lesions: These include  lesions of the optic chiasm itself.
3. Postchiasmal lesions: These include all lesions between the optic chiasm and the visual cortex.

Depending on their topological origin, visual defects manifest themselves in different ways in the results of a visual field examination , which can thus provide indications as to their possible causes. The following sections describe some of the specific features of the three symptom groups named above. Their purpose is not to provide a full medical explanation of the symptoms but merely to point out connections between the possible topological origin of visual field defects and the results supplied by a perimeter.

### 5.4.1. Prechiasmal lesions

Prechiasmal visual field defects are caused by lesions of the visual pathway before the optic chiasm, such as lesions of the retina or optic nerve. These defects are essentially monocular defects, i.e. they may affect only one eye. However, since many diseases affect both eyes at the same time, defects of this kind can also occur in both eyes. This means that prechiasmal lesions cannot be excluded in the case of binocular defects and that they are a highly probable cause in the case of monocular defects.

Prechiasmal visual defects can be very diverse in terms of shape, location and depth, reflecting the variety of their possible causes. The patient may by no means be completely blind in the affected region of the visual field (this is only the case if the defect is absolute); their sensitivity may also only be markedly diminished there. The following examples may give an idea of the possible symptoms.

The first example shows the visual field of a left eye with marked macular degeneration, i.e. retinal disease). If it covers a larger area, geographic atrophy (in cases of dry senile macular degeneration) can result in a central scotoma such as the one shown in Figure 33, Macular degeneration (OS). In this example the right eye is unremarkable.

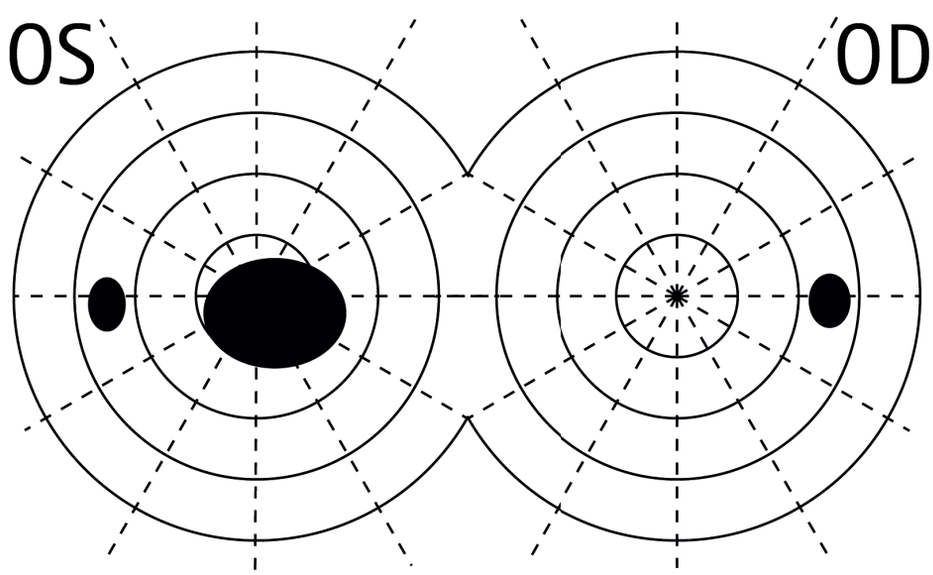



Figure 33, Macular degeneration (OS)

The second example shows the symptoms of retinal detachment in the inferior part of the retina. This defect appears to the affected individual as a curtain that descends downward as the disorder progresses. Depending on the duration of retinal detachment and on the situation it may be a relative or an absolute defect. Figure 34, Curtain-like defect (OD) is a good example of this kind of defect. In this case only the right eye is affected, while the left eye is unremarkable.

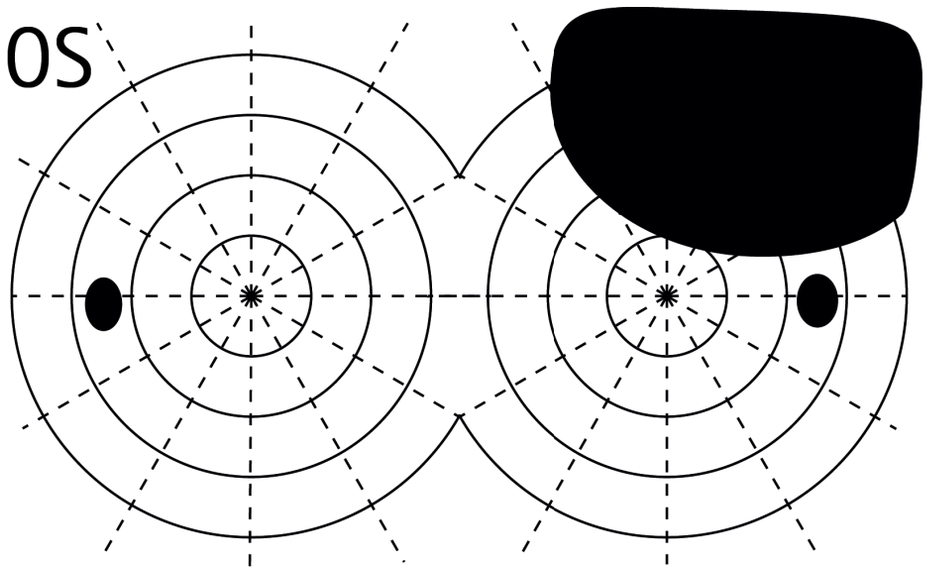



Figure 34, Curtain-like defect (OD)

Another kind of disorder that is essentially monocular are nerve fibre layer defects occuring in glaucoma for example. Figure 35, Nerve fibre layer defect is such an example here affecting the left eye, while the right eye is unaffected. Glaucoma is covered in greater detail in the next chapter.

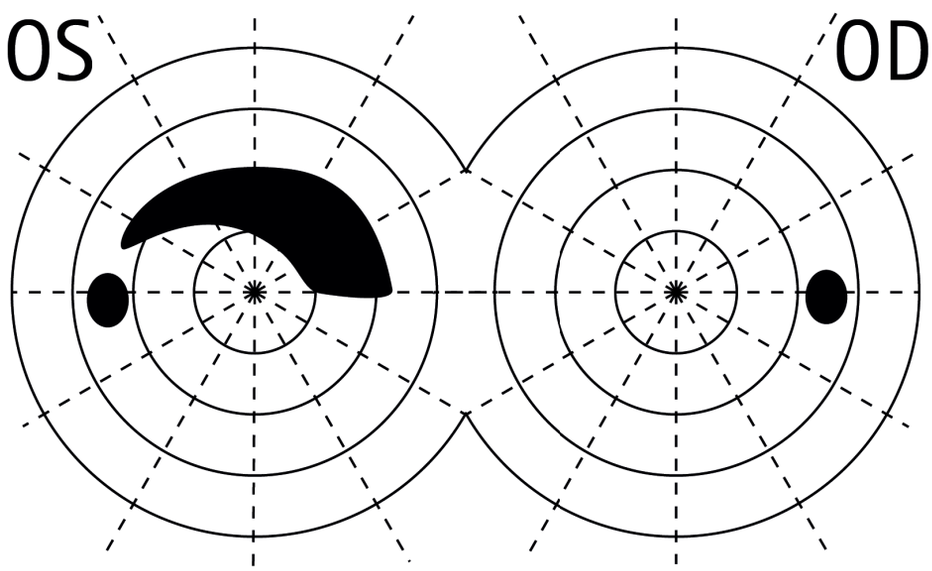



Figure 35, Nerve fibre layer defect

Papilloedema can manifest itself in static perimetry as an enlarged blind spot. The Figure below shows an enlarged blind spot of the right eye, while the left eye shows a normal appearance.

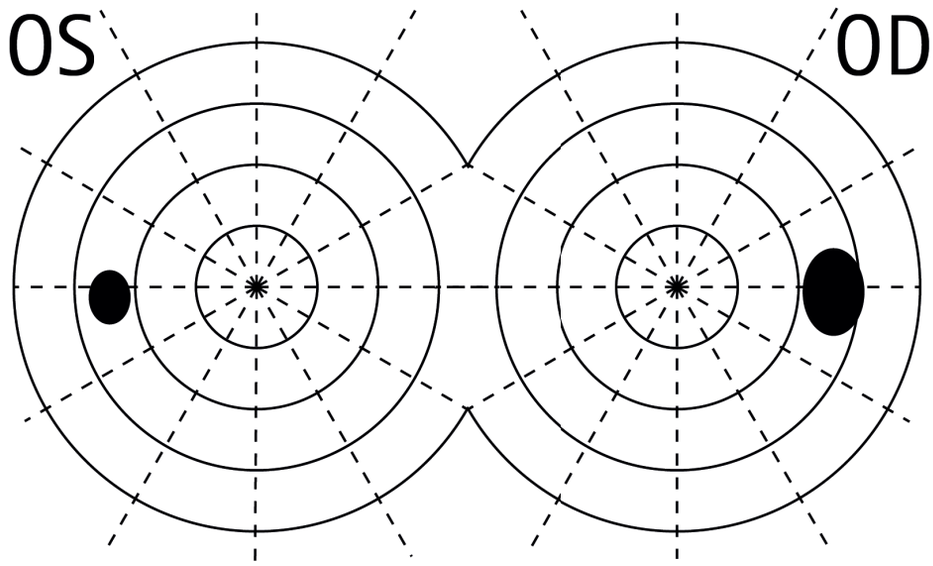



Figure 36, Enlarged blind spot (OD) through swelling of the optic disc

Inflammatory diseases of the optic nerve can lead to central scotomas or centrocecal scotomas shown in Figure 36, Enlarged blind spot (OD) through swelling of the optic disc in a similar way as can be seen with toxic opticopathies and Leber hereditary optic neuropathy.

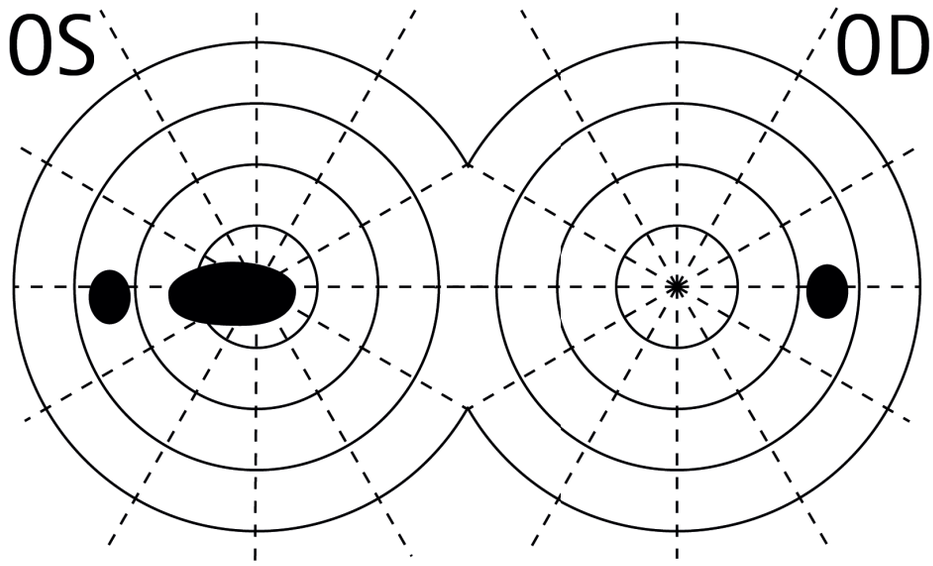



Figure 37, Optic nerve neuritis associated with impaired visual acuity (OS)

### 5.4.2. Chiasmal lesions

The most vulnerable nerves at the optic chiasm are those that cross over to the other side. As can be seen in the Figure Figure 32, Schematic diagram of the visual pathway) showing the visual pathway, these are the fibres that originate in the nasal half of the retina. This is why chiasmal defects affectthe temporal half of the visual field more often than the nasal half. One possible cause is an enlarged pineal gland, as, e.g. in pituitary adenoma.

The visual field defect shown in Figure 38, Bitemporal hemianopsia due to to a large pituitary adenoma - is referred to as complete bitemporal hemianiopsia. It is bitemporal because the temporal side of both eyes are affected, while hemianopsia refers to the fact that the loss of visual function extends to one complete half of the visual field of an eye. It has also been termed "blinker blindness", in reference to the fact that the patient's view can be constricted as if they were wearing blinkers.

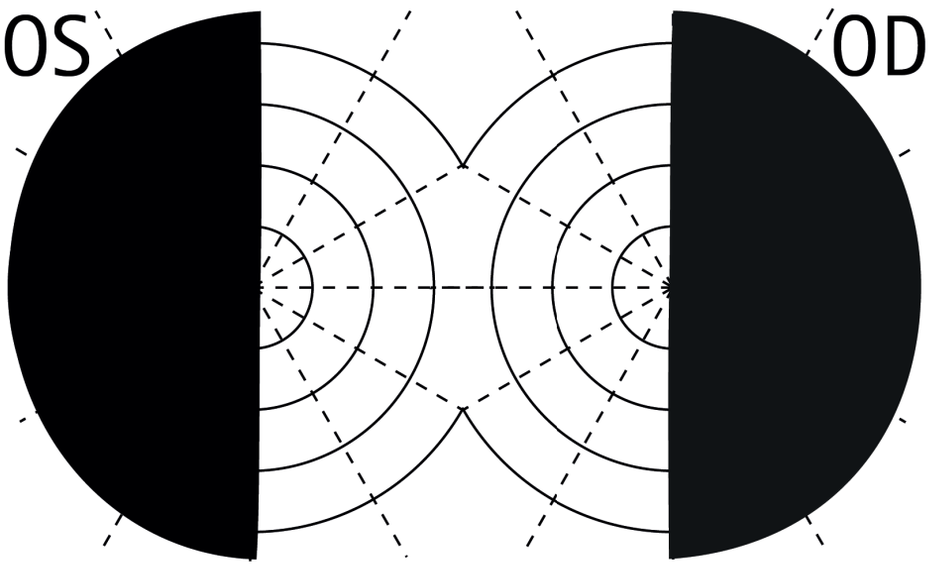



Figure 38, Bitemporal hemianopsia due to to a large pituitary adenoma

### 5.4.3. Postchiasmal lesions

One characteric symptom of lesions posterior to the optic chiasm is the occurrence of homonymous visual field defects, where the visual fields of both eyes are affected on the same side. As can be inferred from the visual pathway, depicted in Figure 39, Complete right homonymous hemianopsia resulting from a stroke in the left brain hemisphere, sensations in the left half of the visual field of both eyes are processed in the right brain hemisphere, while those in the right half are processed in the left brain hemisphere. Due to this arrangement postchiasmal visual field defects in most cases do not extend across the vertical main meridian of either eye.

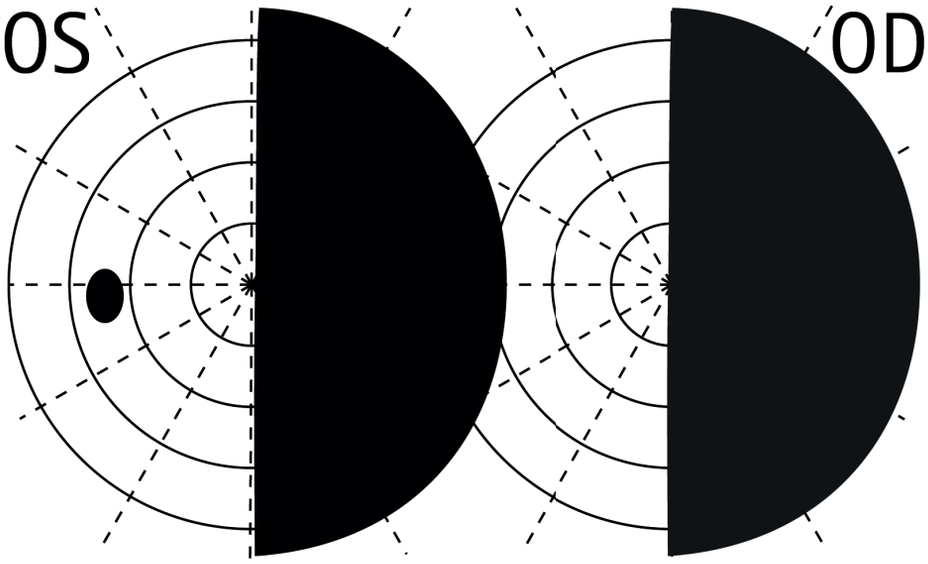



Figure 39, Complete right homonymous hemianopsia resulting from a stroke in the left brain hemisphere

The second example of a postchiasmal defect shown here is a case of incongruent homonymous quadrantanopsia in the left superior part of the visual field Figure 40, Incongruent left superior homonymous quadrantanopsia. The attribute incongruent refers to the fact that the defects in the left and right visual field do not match exactly, while homonymous indicates that the visual fields of both eyes are affected on the same side, and quadrantanopsia, means that the defects are each limited to one visual field quadrant. This example illustrates that the visual field defects caused by a postchiasmal lesion need not necessarily have the same shape and size for both eyes.

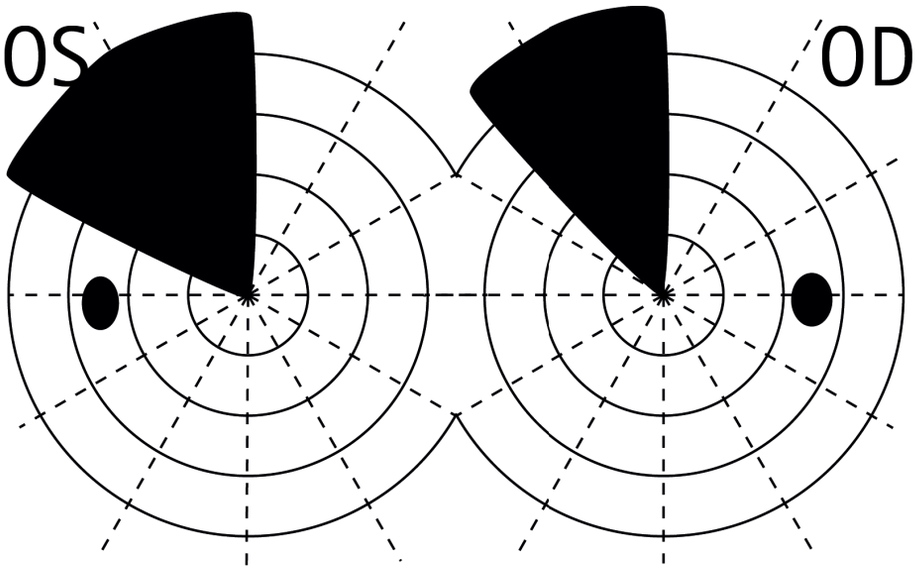



Figure 40, Incongruent left superior homonymous quadrantanopsia

## 5.5. Topology of Visual Field Defects

Visual field defects can be classified not only with respect to their location origin but also according their location and size in the visual field. Using the latter two criteria visual field defects can be divided into three groups:

1. Depression /constriction
2. Field cuts / sector defects
3. Scotomas

### 5.5.1. Depression / Constriction

In depression or constriction the sensitivity of the visual is globally diminished. Which of these two terms applies depends on the examination method being used: In static perimetry the defect is referred to as a depression, while in kinetic perimetry it is called a constriction.

### 5.5.2. Field Cuts / Sector Defects

Field cuts or sector defects are characterized by an inward shift of the visual field boundary. One possible cause of this is retinal detachment. They are variously also described as curtain defects. Figure 42, A sector defect on the examination printout of the OCULUS Twinfield® shows an examination printout from an OCULUS Twinfield® perimeter which unmistakably documents a sector defect. In the greyscale map the defect appears as if it were draped before the visual field like a curtain. The cumulative defect curve shows a sharp downward bend, which is typical when a certain region of the visual field loses all light sensitivity.

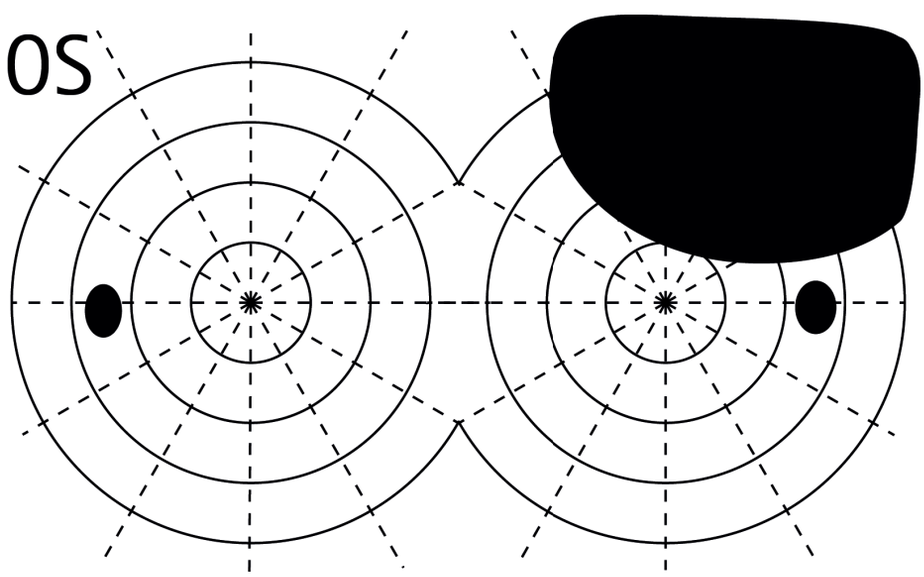



Figure 41, Example of a sector defect (OD)

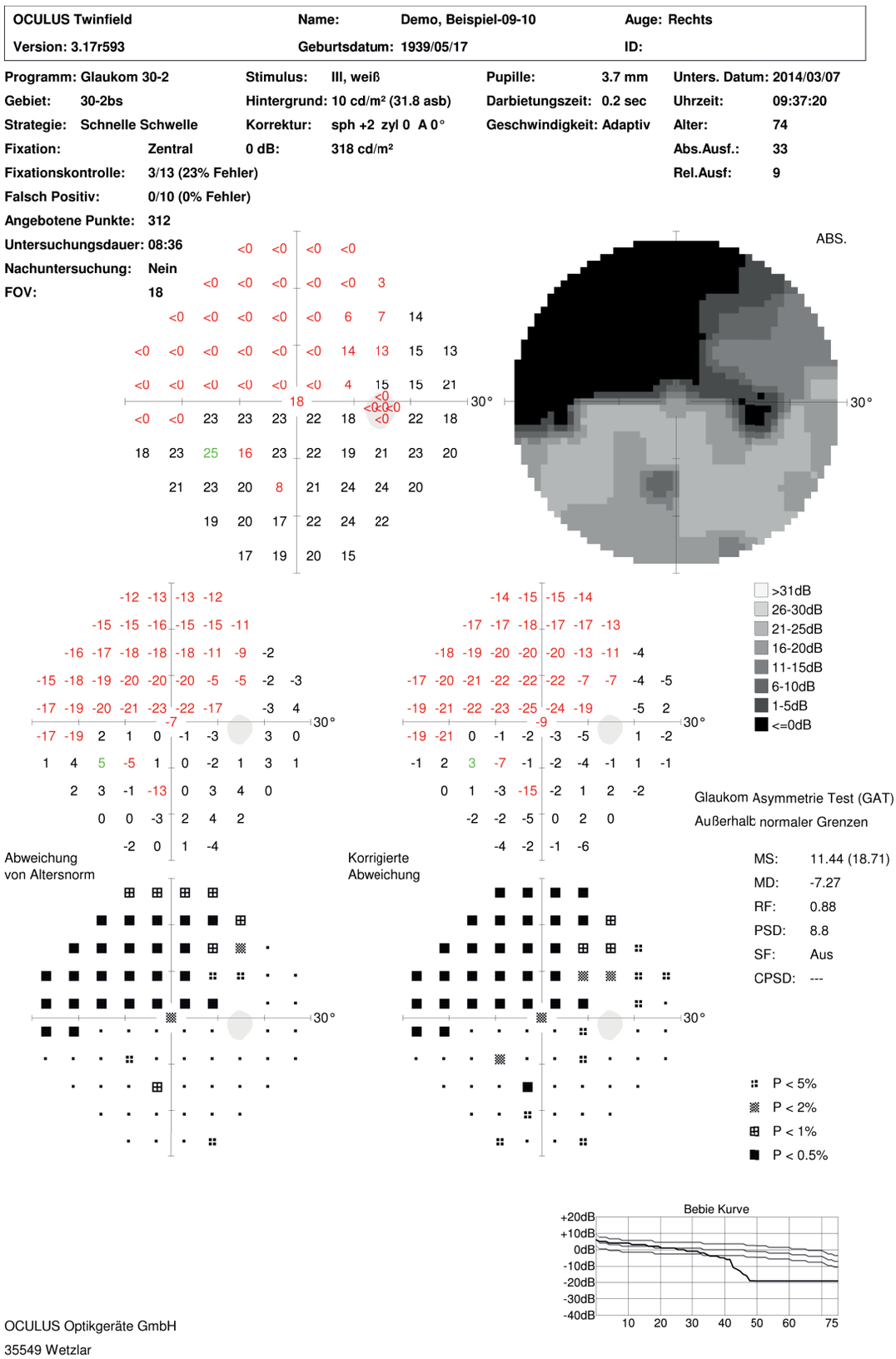



Figure 42, A sector defect on the examination printout of the OCULUS Twinfield®

### 5.5.3. Scotomas

Scotomas are insular defects, meaning that they do not extend to the boundary of the visual field. Their shape, location, steepness and depth vary depending on the cause and the stage of the disorder. An absolute scotoma is a region of the visual field that shows zero sensitivity to even the brightest available light stimulus, i.e. to which the affected indiviual is completely blind. A relative scotoma still shows sufficient sensitivity to bright stimuli, but not to weaker stimuli; i.e. sensitivity in this region is significantly below normal. A relative scotoma can be deep or shallow. A deep scotoma is a region of the visual field which is sensitive to only the strongest stimuli, whereas in a shallow scotoma sensitivity is impaired to only the weakest stimuli.

The category of defect depth is only used in static perimetry. It is used to quantatively classify scotomas into degrees of severity.

Figure 43, Central scotoma shows an example of what is called a central scotoma. One possible cause of this is macular degeneration, but of a degree that still permits central fixation.

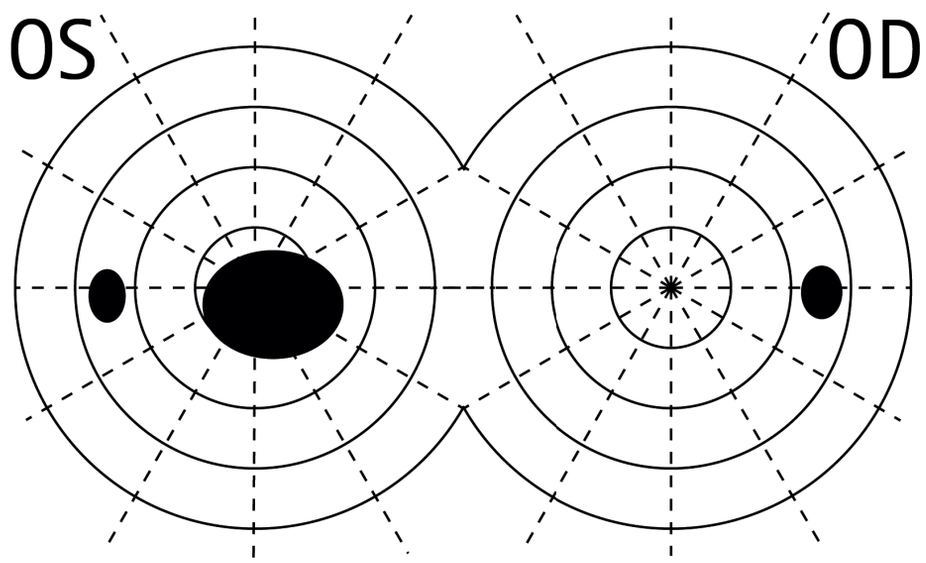



Figure 43, Central scotoma

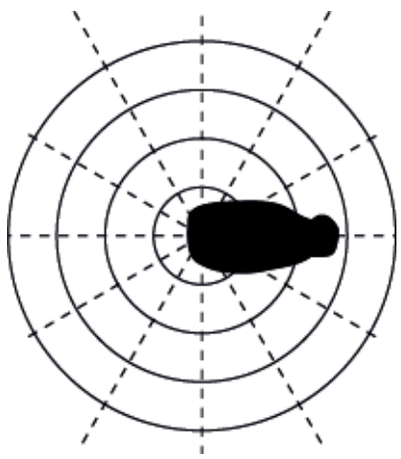


Figure 44, Centrocoecal scotoma

Figure 44, Centrocoecal scotoma shows what is referred to as a centrocoecal scotoma. This is characterized by a defect spreading from the blind spot towards the line of sight. This type of scotoma may be the result of an optic nerve lesion.

Figure 45, shows a paracentral scotoma, which is characterized by a local defect near the point of fixation.

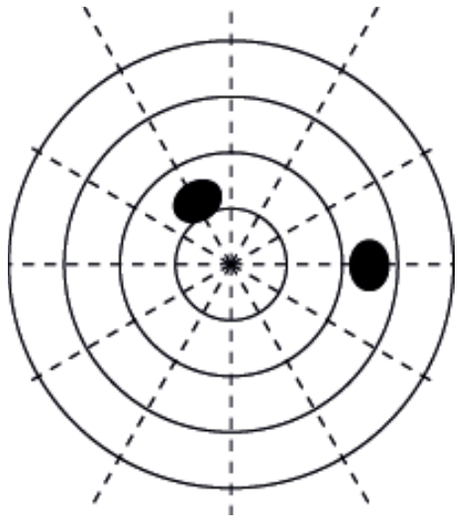


Figure 45, Paracentral scotoma

A ring scotoma, also termed paracentral scotoma, appears as a ring placed around the point of fixation **(Figure 46, Ring scotoma)**. One possible cause of this is the toxic effect of chloroquine.

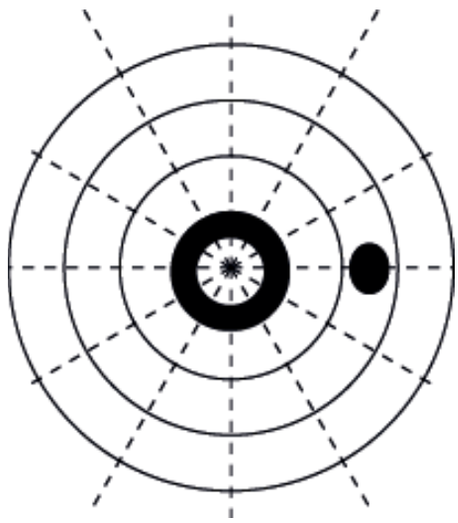


Figure 46, Ring scotoma

Another type of defect is Bjerrum's scotoma, which extends around the fixation point in an arc, usually in the range between 10° and 20° eccentricity (Figure 47, Seidel's scotoma), and is considered to be typical of open angle glaucoma.

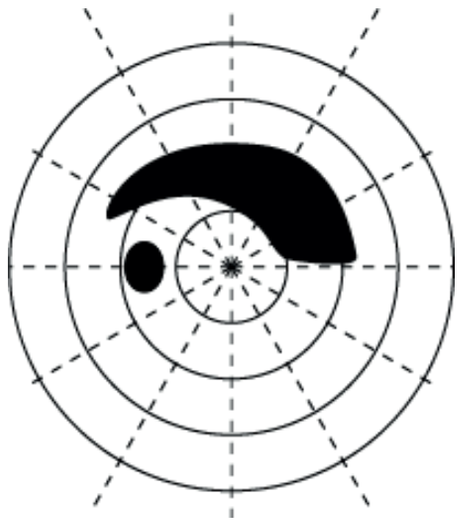


Figure 47, Seidel's scotoma

# 6. The Visual Field in Glaucoma

According to Douglas R. Anderson, glaucoma is "the most common reason for performing a visual field test in the usual clinical practice". The following sections explain the fundamentals of glaucoma, illustrating its progression as it manifests itself in representations of visual field function.

## 6.1. Basic Medical Information on Glaucoma

The term glaucoma refers to a number of diseases which all have a common outcome if they are not recognized in time, namely the destruction of the optic nerve anterior to the optic chiasm. The most common form is open angle glaucoma, where, unnoticed by the affected individual, the canals that drain the aqueous fluid gradually clog up. As a result, the aqueous fluid cannot be discharged at the same rate as it is formed, leading to an increase in intraocular pressure. Over time, the eyeball begins to bulge at its mechanically weakest point, the optic nerve head. This causes damage to the optic nerve fibres, or axons, resulting in impairment or loss of vision in the regions of the visual field served by the affected axons. If the disease goes untreated, more and more axons are damaged, eventually causing total blindness of the affected individual. Visual function that is lost in this way cannot be restored by any treatment. However it is possible to control intraocular pressure by medical means, preventing further damage.

Another very common type of glaucoma is normal-tension glaucoma, where the optic nerve is damaged even though intraocular pressure is not higher than normal. The disease mechanism here appears to involve an inability of the optic nerve to withstand even normal intraocular pressure.

Angle closure glaucoma, also termed acute glaucoma or glaucoma attack, is much rarer than the two conditions described above. It is caused by a sudden clogging of the drainage canals, resulting in a rapid rise in intraocular pressure and sudden symptoms such as headache, eye pain, nausea, appearance of rainbow-coloured rings around lights at night and blurred vision.

The above variants all fall under the category of primary glaucoma, because they are not a secondary consequence of some other disease or damage. However, there are a number of disorders that secondarily lead to glaucoma. In most of these cases the glaucoma can be contained by treating the primary cause.

Finally there are cases of congenital glaucoma, in which the chamber angle has not developed sufficiently for the aqueous fluid to drain properly. Congenital glaucoma requires immediate treatment. Since visual field examinations are not possible with infants, it will not be discussed any further in this introduction.

If detected sufficiently early, glaucoma can be treated by medication or surgery. As long as no severe loss of vision has occured, the affected individual's eyesight can be preserved. However, it is unfortunately not possible, by any currently available method, to restore visual field function in already affected regions. This points to the importance of regular glaucoma screening. For the same reason, follow-up examinations are very important for preserving visual field function in cases where a screening test has yielded positive results. This holds all the more as there is no or only minor loss of visual field function in the early stages of glaucoma. Due to the incipient course of the disease, glaucoma is often not noticed by the affected individual until it has reached an advanced stage. Visual field examinations can thus make a valuable contribution to the prevention and to the control of already existing glaucoma.

## 6.2. Functional Staging of Glaucoma According to Aulhorn

The development of visual field defects caused by glaucoma was first examined and classified by Prof. Dr. E. Aulhorn. Each stage is characterized by specific visual field symptoms, which reflect the increasing damage to the optic nerve fibres as the disease progresses Figure 48, Glaucoma stages as described in "Rasterperimetrie mit dem Tübinger Automatik Perimeter", F. Doner-Schandl, W. Durst, G. Kolling, B. Leo-Kottler, Tübingen, Germany, 1993.

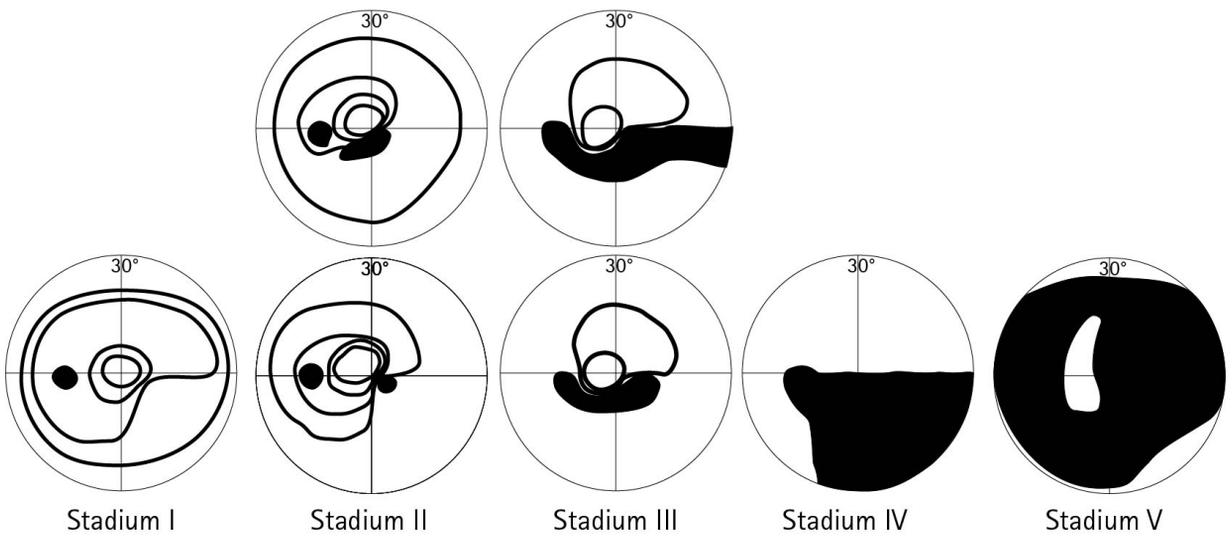



Figure 48, Glaucoma stages as described in "Rasterperimetrie mit dem Tübinger Automatik Perimeter", F. Doner-Schandl, W. Durst, G. Kolling, B. Leo-Kottler, Tübingen, Germany, 1993

Aulhorn distinguished five stages of glaucoma disease:

| | |
|---|---|
| stage 1: | relative scotoma in the region of the affected axons; |
| stage 2: | small absolute scotoma in the Bjerrum region, but no confluence with the blind spot; |
| stage 3: | absolute scotoma in the Bjerrum region confluent with the blind spot, followed in due course by formation of a "nasal step" as described by Rønne; |
| stage 4: | progressive expansion of the scotoma across the visual field; |
| stage 5: | obliteration of the entire visual field. A small island of vision may remain temporally. |

Glaucomatous scotomas are typically arc-shaped and located in the Bjerrum region (Bjerrum's scotomas). Figure 49, Course of the axons on the retina above shows the course of axons through the retina. Note that this is a two-dimensional representation of the eye's concave spherical inner surface. The image illustrates how it is that glaucomatous scotomas are often arcuate in shape.

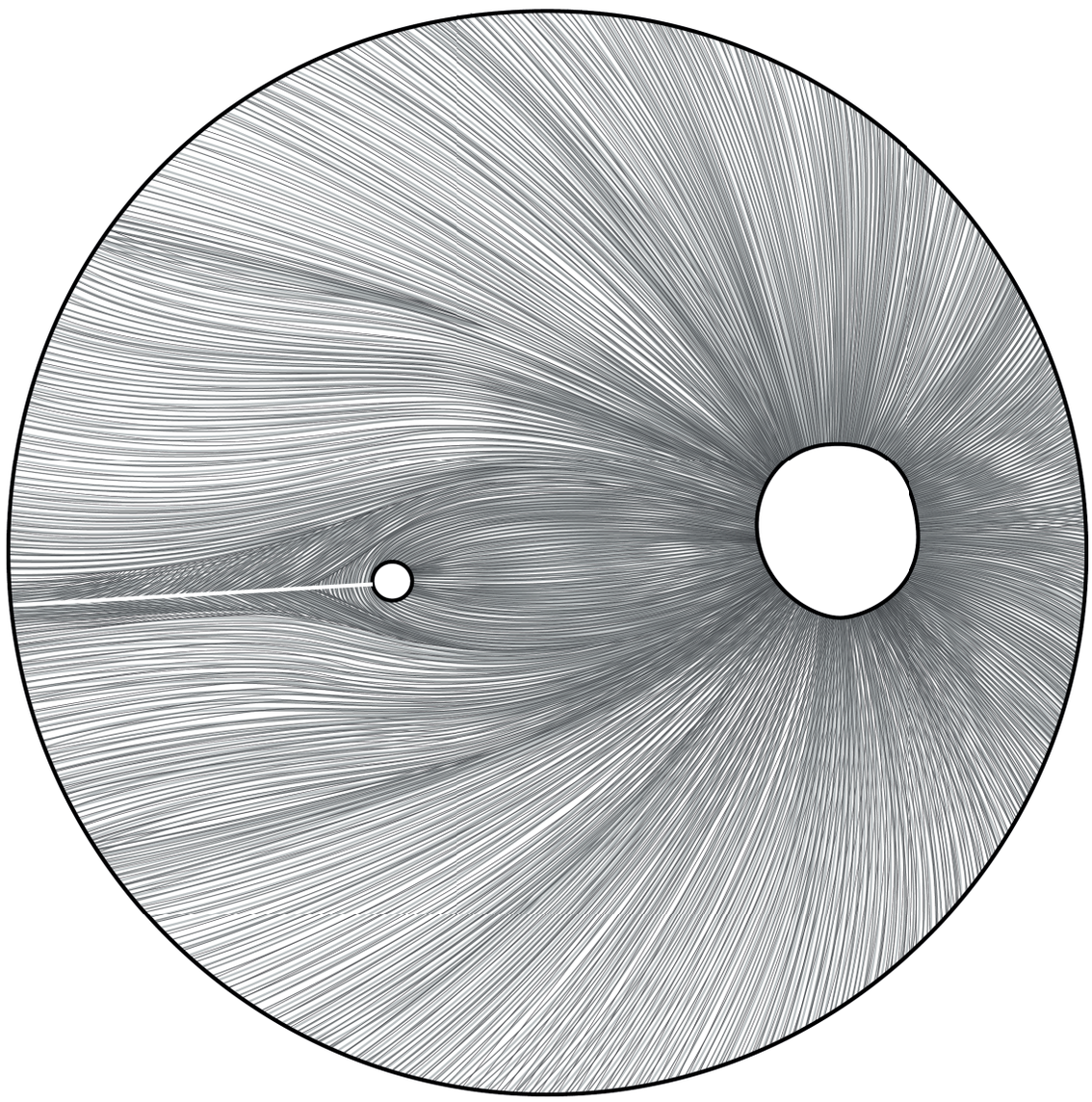
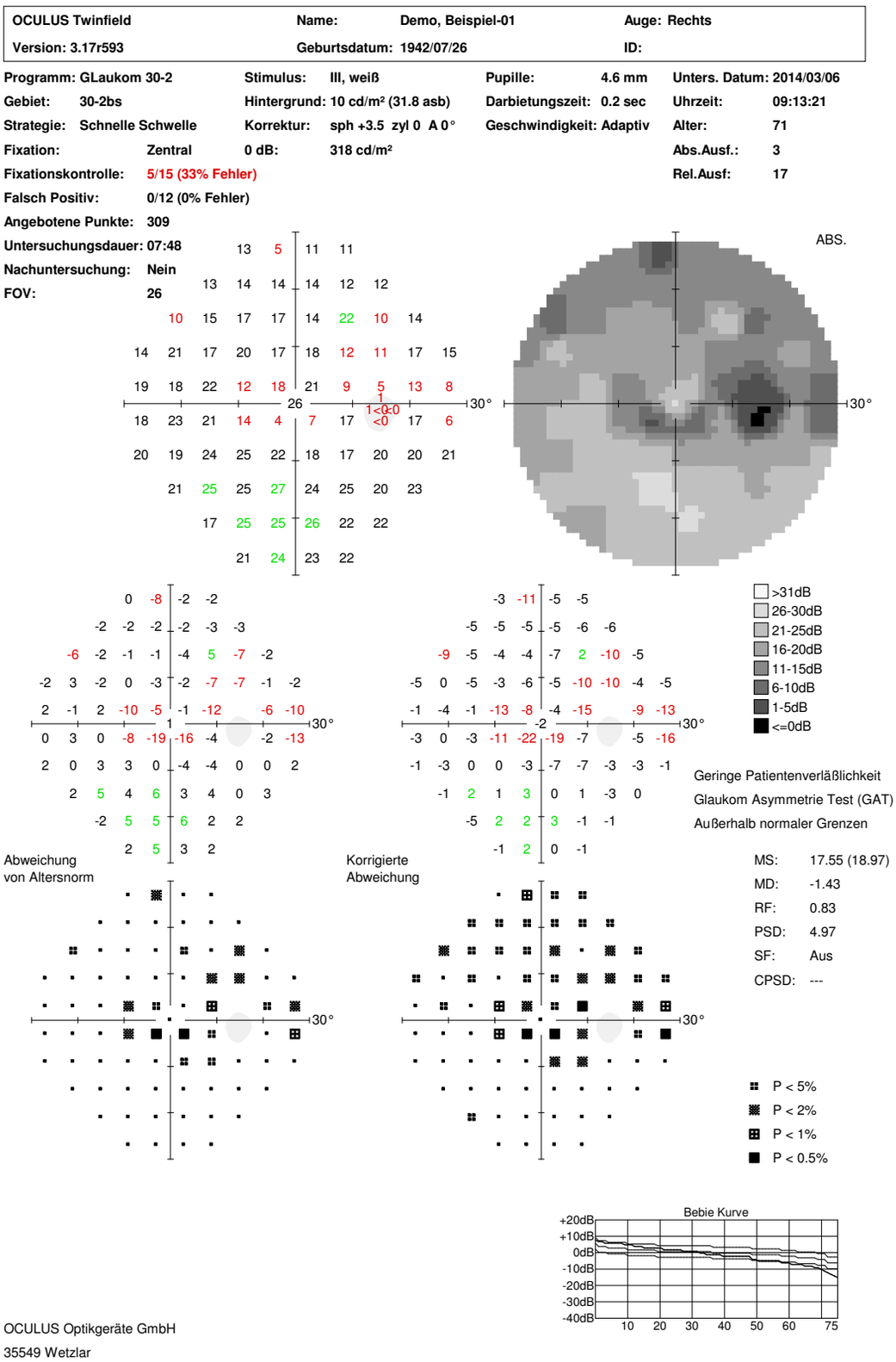


Figure 49, Course of the axons on the retina

## 6.3. Examples of Examination Printouts in Glaucoma

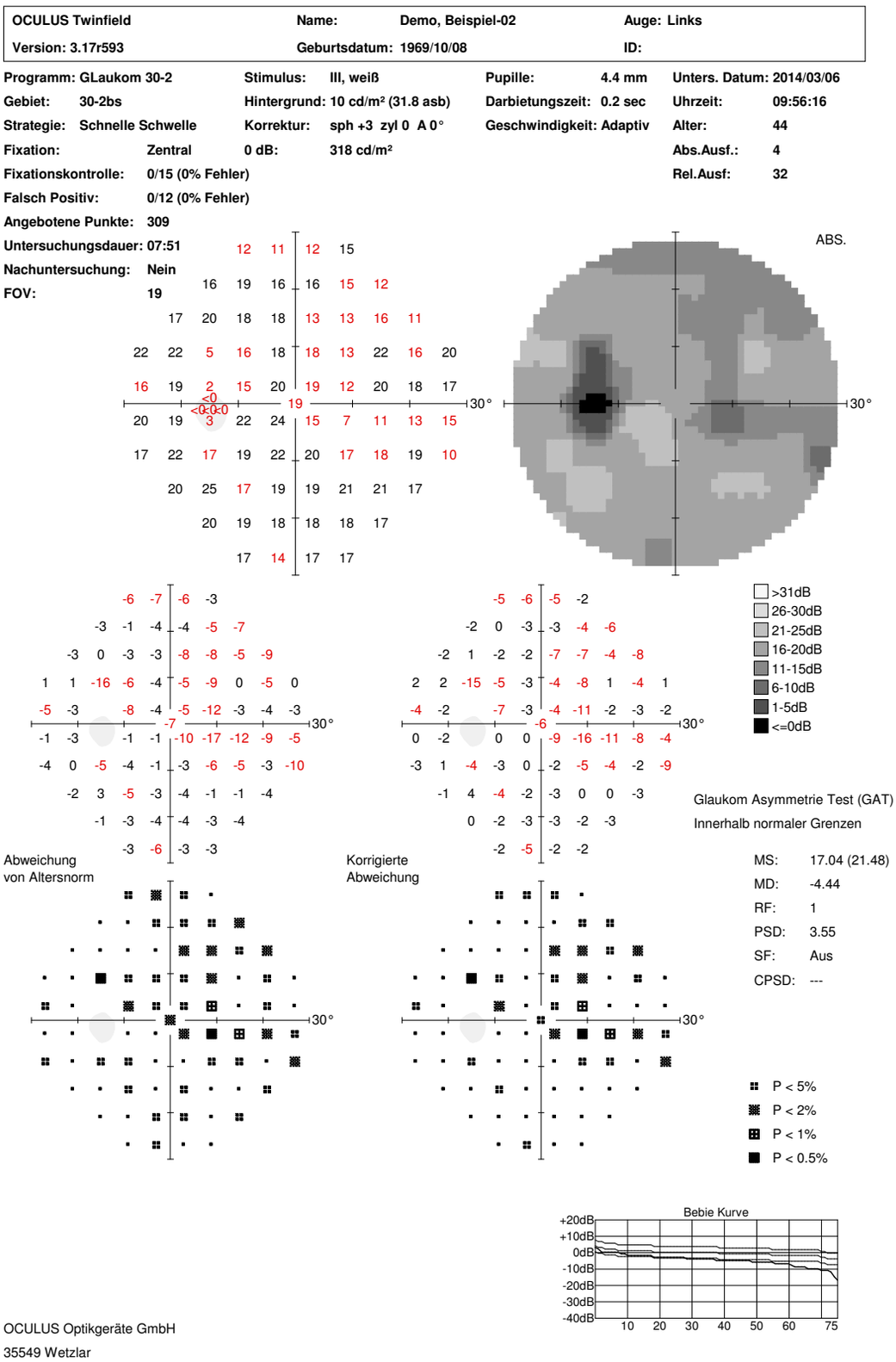
On the following pages some example printouts obtained with different OCULUS perimeters are shown and explained. At least one example is presented of each glaucoma stage. The examination printouts are intended as reference examples that will familiarize the physician with the representation methods used.

## Example 1: Stage 1 glaucoma



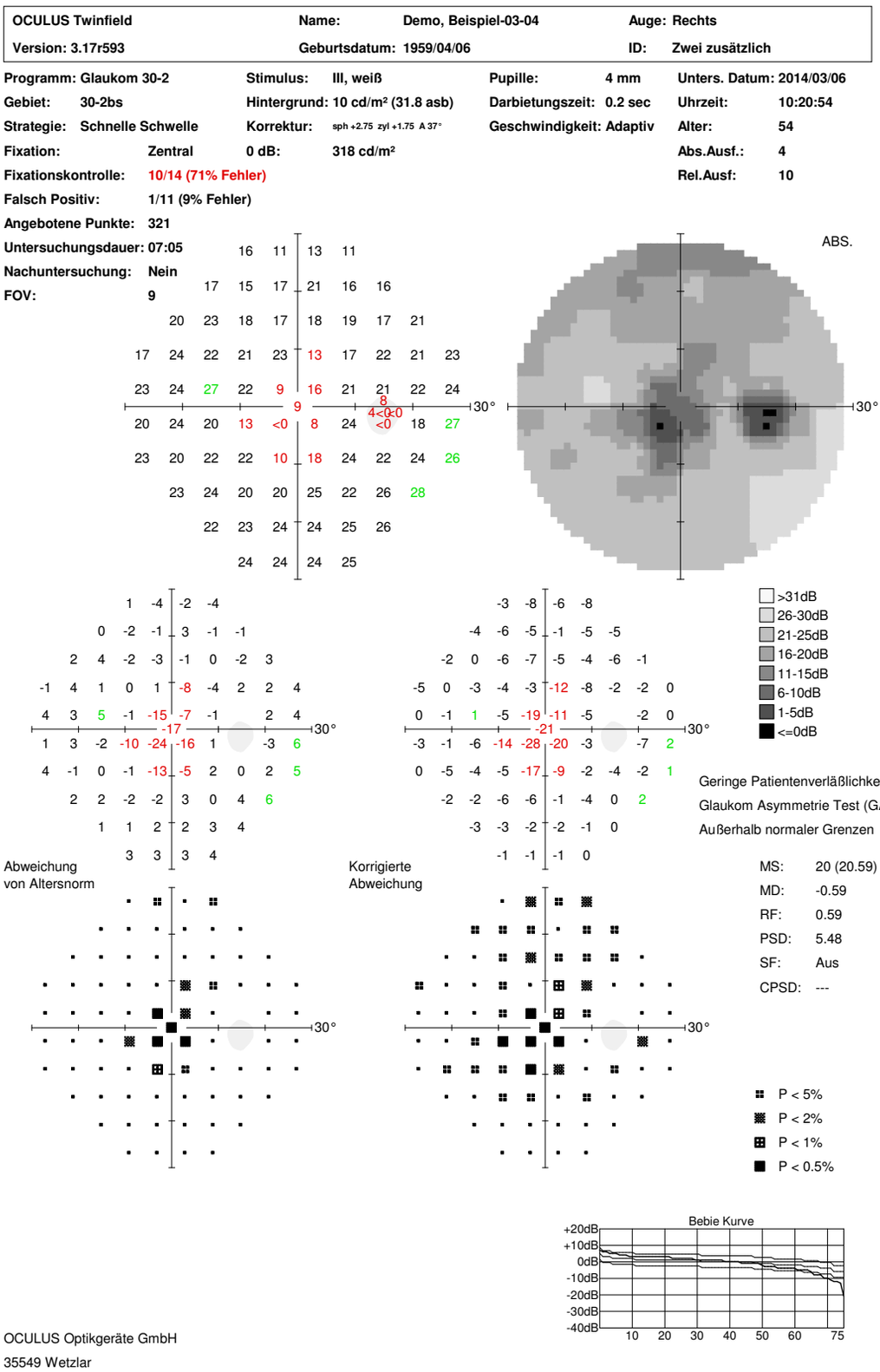

The printout shows an enlarged blind spot as well as a relative arcuate scotoma inferior to the fovea. Since none of the scotomas are absolute, this finding classifies as Aulhorn stage 1 glaucoma

## Example 2: Enlarged blind spot



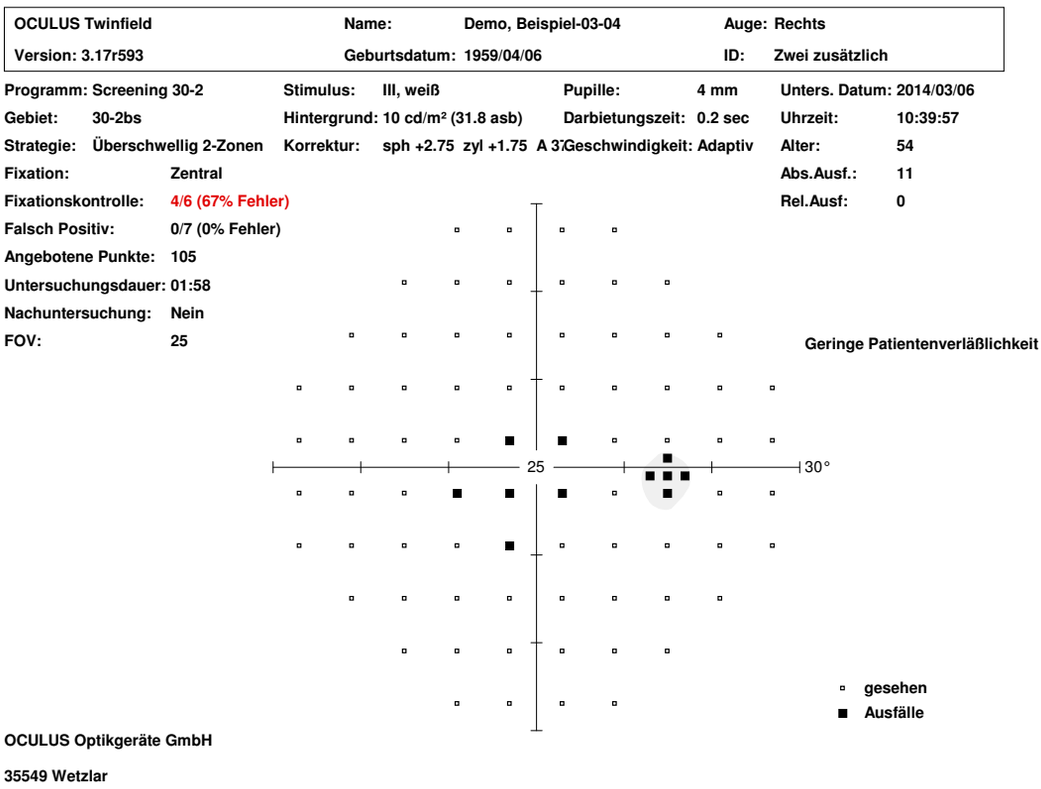

This visual field shows an enlarged blind spot bordered by a relative scotoma. A further scotoma can be seen to the right just inferior to the horizontal main meridian.

## Example 3: Absolute glaucomatous scotoma



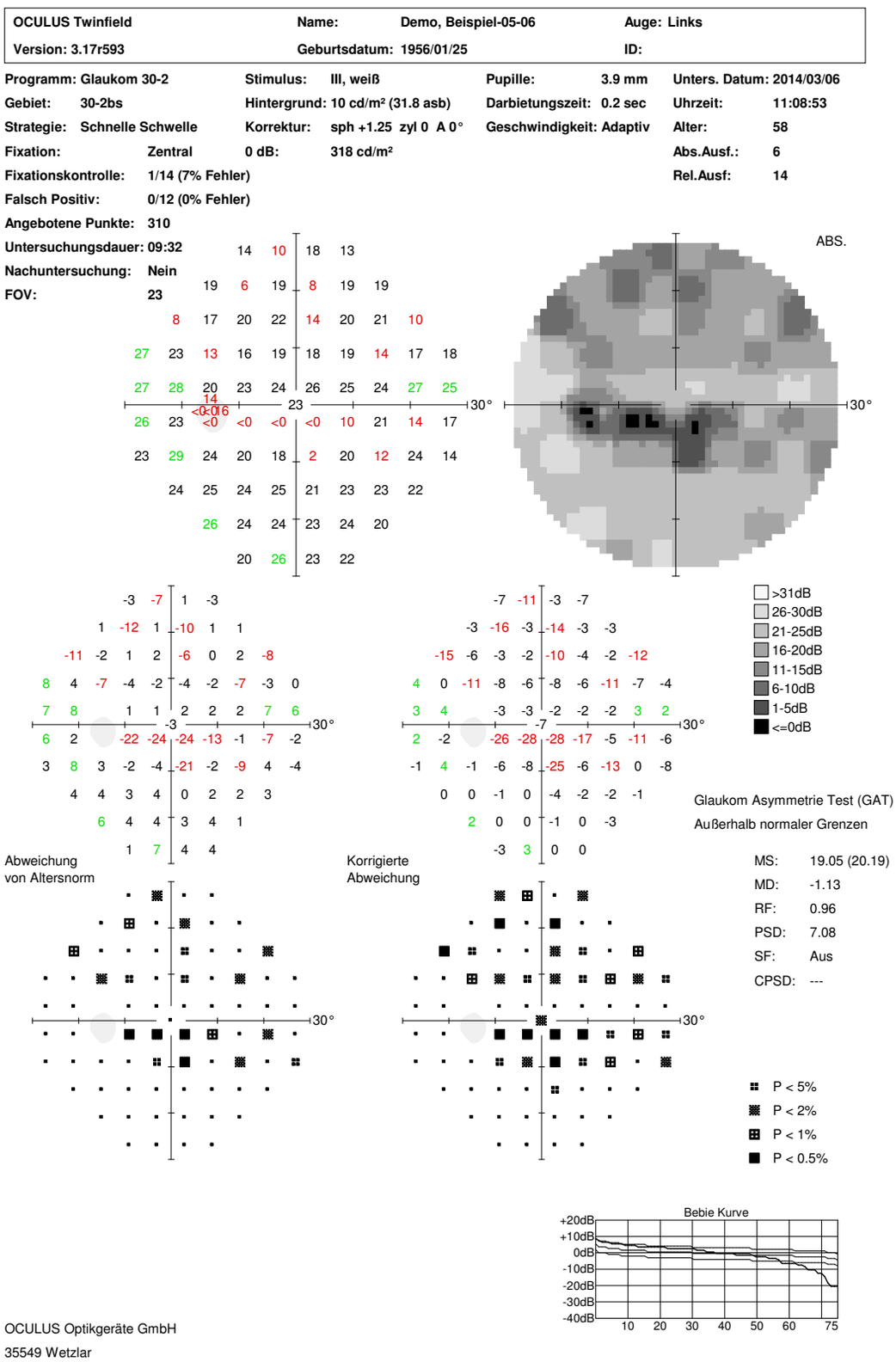

Here an absolute scotoma can be seen just inferior to the fovea and to the left of the vertical main meridian. This scotoma is also the result of glaucoma, but since it is absolute, it classifies as Aulhorn stage 2 glaucoma.

## Example 4: Using threshold strategies in glaucoma




This printout shows the result of an examination of the same patient as in Example 3, the difference being that the examination was based on the Suprathreshold 2-Zone Strategy.

## Example 5: Stage 3 glaucoma

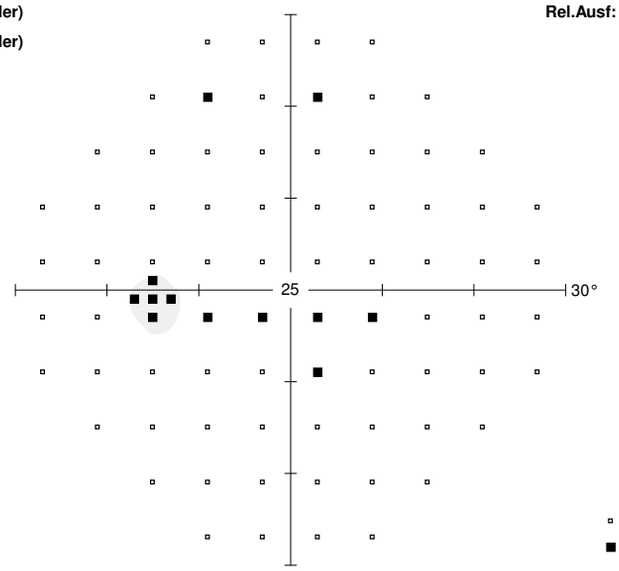



This examination printout shows an arcuate scotoma that is partly absolute and also confluent with the blind spot. Since this is a case of glaucoma, it classifies as Aulhorn stage 3 glaucoma.

## Example 6: Suprathreshold strategy in stage 3 glaucoma

| | | | | | |
|---|---|---|---|---|---|
| OCULUS Twinfield | | Name: | Demo, Beispiel-05-06 | Auge: | Links |
| Version: 3.17r593 | | Geburtsdatum: | 1956/01/25 | ID: | |
| Programm: | Screening 30-2 | Stimulus: | III, weiß | Pupille: | 4 mm |
| Gebiet: | 30-2bs | Hintergrund: | 10 cd/m² (31.8 asb) | Darbietungszeit: | 0.2 sec |
| Strategie: | Überschwellig 2-Zonen | Korrektur: | sph +1.25 zyl 0 A 0° | Geschwindigkeit: | Adaptiv |
| Fixation: | Zentral | | | | |
| Fixationskontrolle: | 0/6 (0% Fehler) | | | | |
| Falsch Positiv: | 0/7 (0% Fehler) | | | | |
| Angebotene Punkte: | 105 | | | | |
| Untersuchungsdauer: | 02:10 | | | | |
| Nachuntersuchung: | Nein | | | | |
| FOV: | 25 | | | | |

| | |
|---|---|
| Unters. Datum: | 2014/03/06 |
| Uhrzeit: | 11:31:38 |
| Alter: | 58 |
| Abs.Ausf.: | 12 |
| Rel.Ausf: | 0 |

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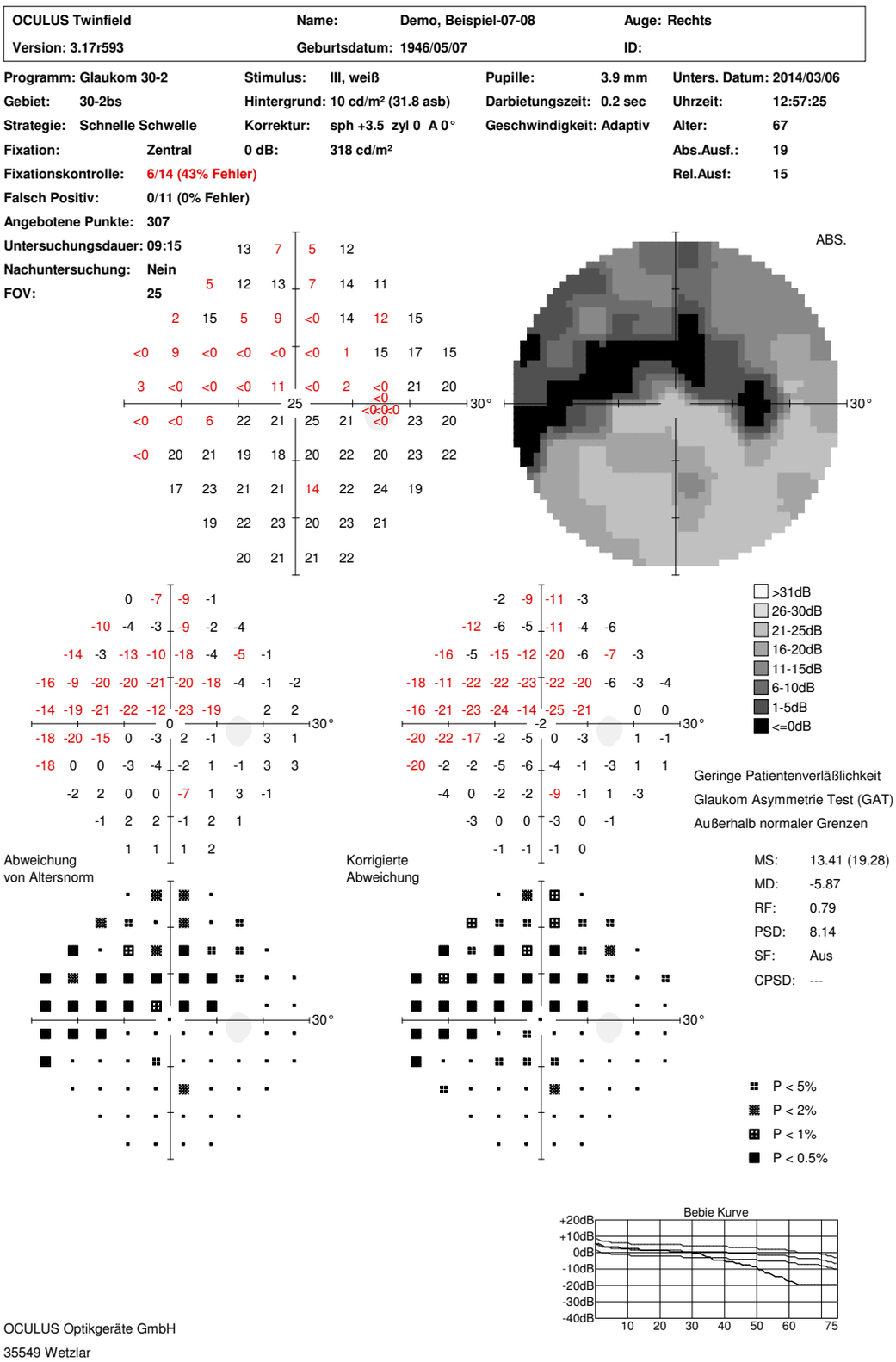
35549 Wetzlar

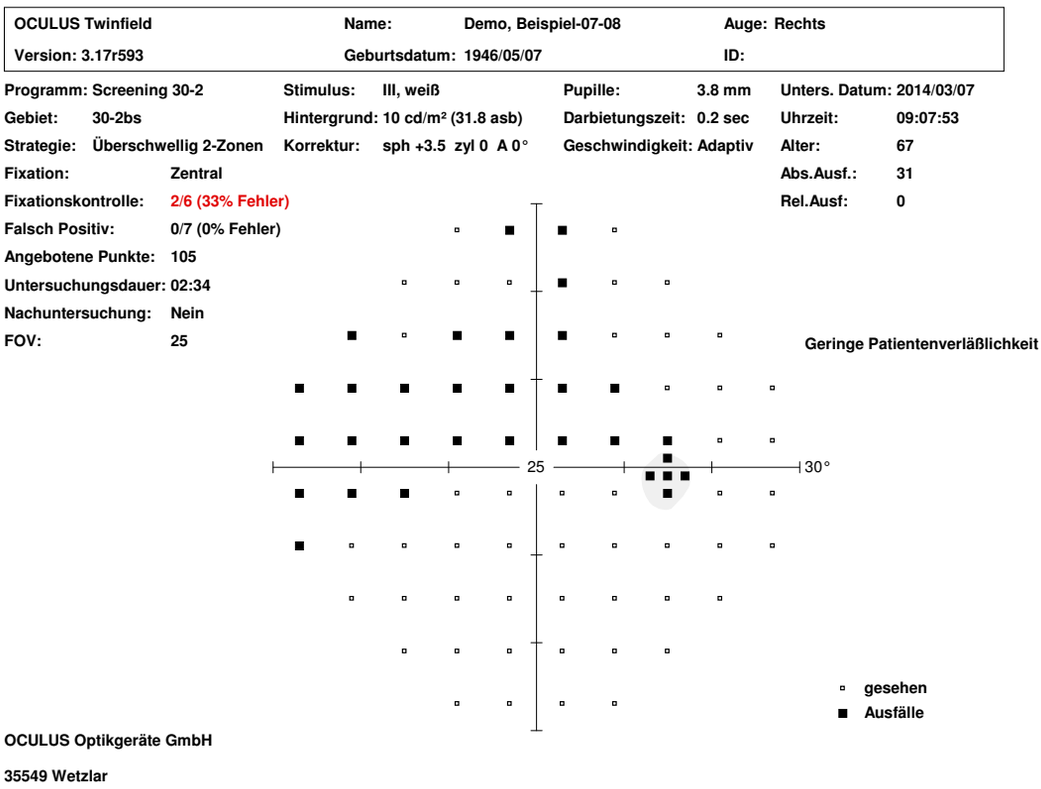
This examination printout is from the patient as the one in Example 5, the difference being that the examination was based on the Suprathreshold 2-Zone Strategy. The results are in agreement with respect to the location of the absolute defect

## Example 7: Stage 3 glaucoma



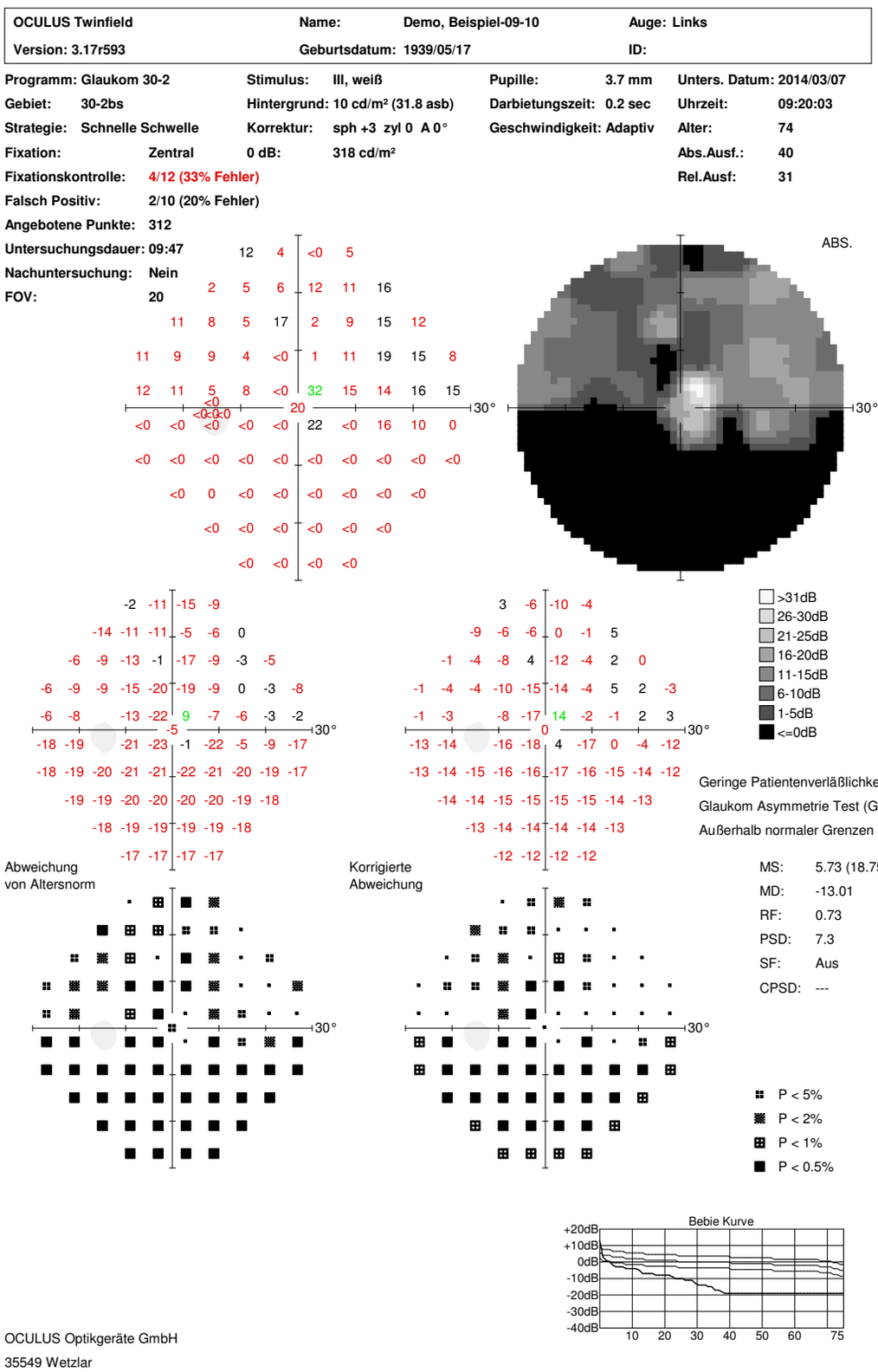

This examination printout shows a case of Aulhorn stage 3 glaucoma. It shows a nasal sector defect that is confluent with the blind spot and can clearly be identified as a case of Rønne's nasal step.

## Example 8: Suprathreshold strategy in stage 3 glaucoma



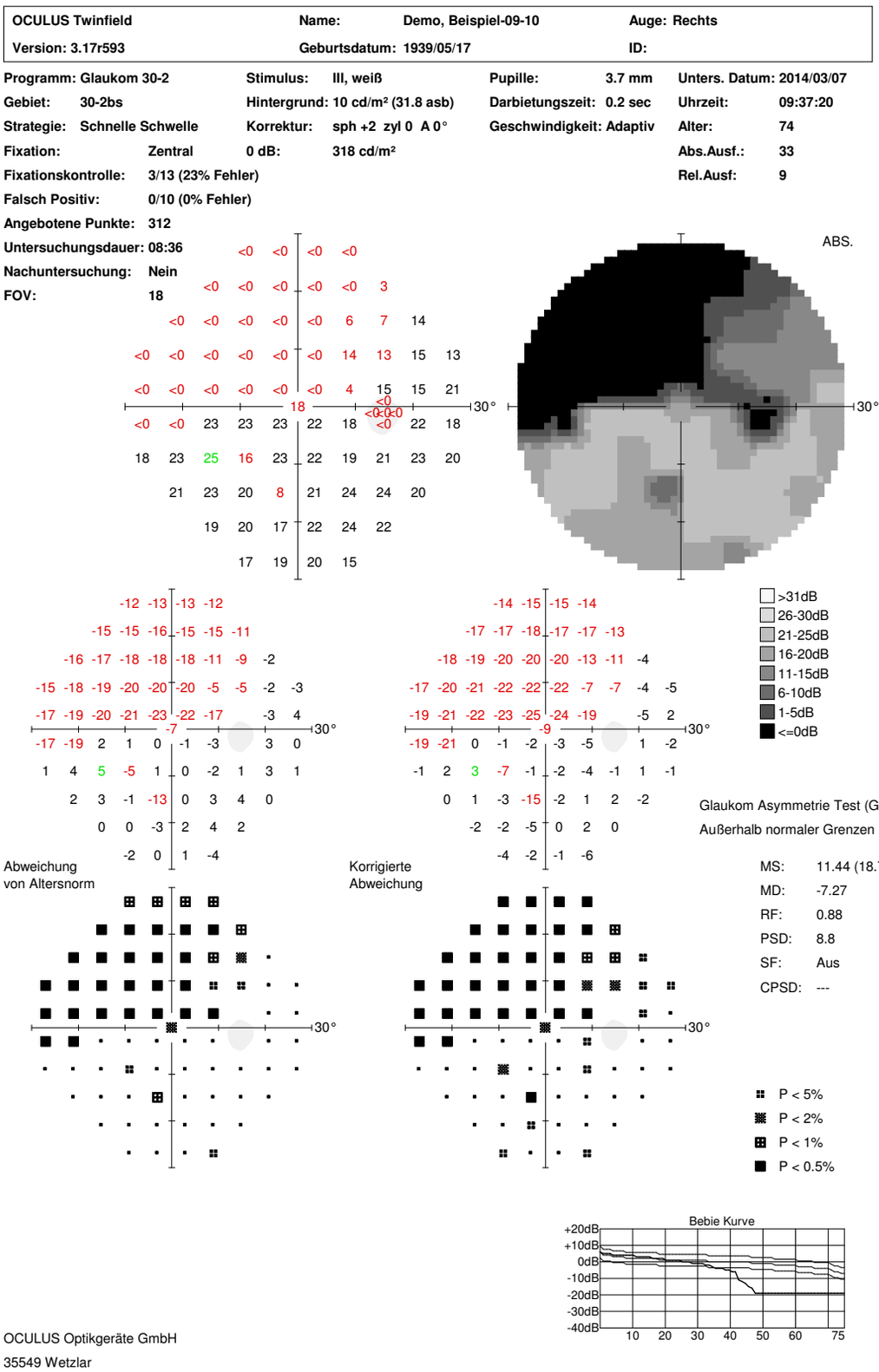

This examination printout is from the same patient as the one in Example 7, the difference being that it was obtained using the Suprathreshold 2-Zone Strategy.

## Example 9: Stage 4 glaucoma



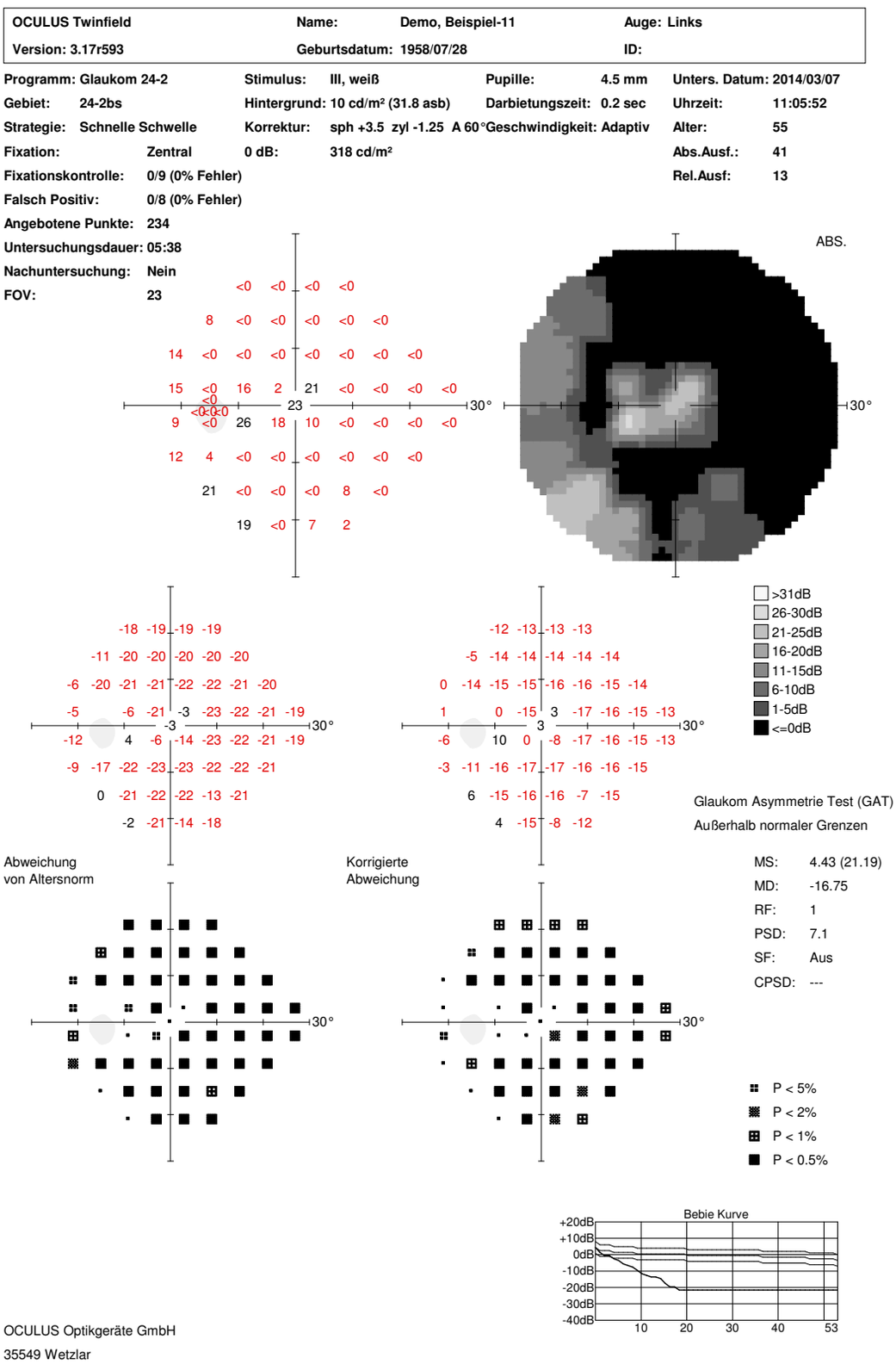

The large defect in the inferior part of the visual field is attributable to glaucoma. A large part of the visual field has already been destroyed by an absolute scotoma, and the finding therefore classifies as Aulhorn stage 4 glaucoma.

## Example 10: Stage 4 glaucoma



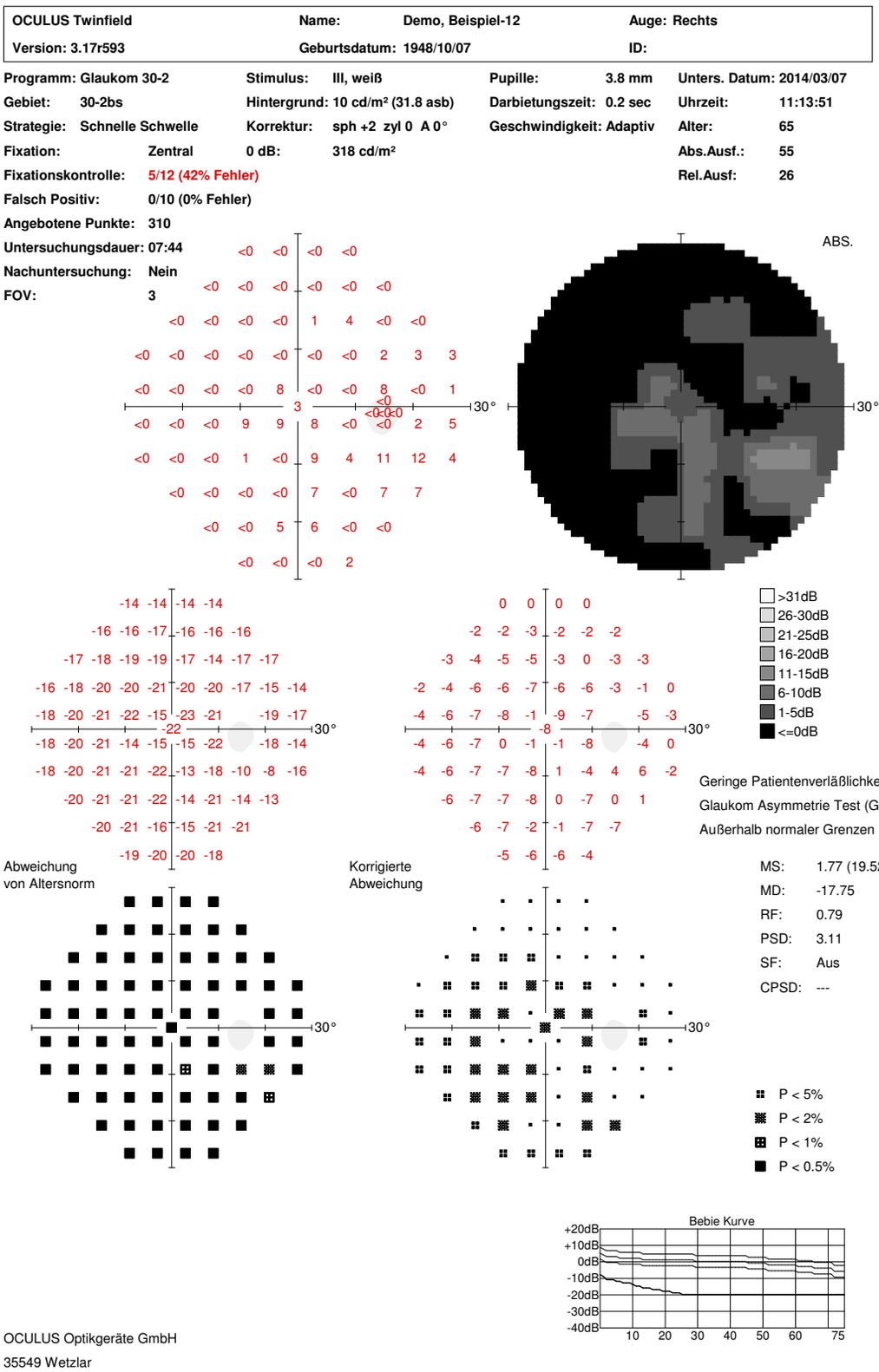

This examination printout likewise shows a case of Aulhorn stage 4 glaucoma. The absolute defect is not as large as the one in Example 9, but it nevertheless already covers one complete quadrant of the visual field.

## Example 11: Stage 5 glaucoma




This is an example of Aulhorn stage 5 glaucoma. The visual field is almost entirely obliterated, with only a small intact area remaining in the centre. Interestingly, the foveal threshold is still 33 dB, which is quite close to normal.

## Example 12: Stage 5 glaucoma




In this case of Aulhorn stage 5 glaucoma the eye under examination has lost virtually all visual function.

# 7. Unique Glaucoma-Related Features of OCULUS Perimeters

Glaucoma care represents the most frequent reason for performing a visual field test in clinical practice.

The main focus when performing a visual field exam should be:

- the results allow a proper assessment;
- the patient's progress can be documented and reviewed;
- and the available examination methods meet or are adaptable to the requirements of routine clinical practice.

## 7.1. Performing the Examination

There are a number of test patterns that are commonly used in perimetry for excluding or assessing glaucoma and are contained in the instruments of many manufacturers. These are also available in OCULUS perimeters, with the difference that here they are harnessed to algorithms not offered by any other manufacturer.

### 7.1.1. SPARK Strategy

The SPARK Strategy has already been covered in detail in chapter 3.4.1.4. SPARK Strategy. Below the most important features of this perimetric examination strategy will only be recapitulated:

- Very short examination time: Full threshold values can be a achieved in a very short time compared to other used strategies. This provides the practical advantage of enabling more patients to be examined within the same time.
- Predictability of duration: The duration of the examination does not depend on the patient. Even patients with severely impaired visual field function can be examined in a short time.
- Repeatability: Examinations based on the SPARK Strategy yield results of ca. 40% lower variability compared with other strategies.
- Designed for progression analysis: The averaged final results of SPARK-based examinations are optimally suited for performing trend analyses such as those available in the Threshold Noiseless Trend (TNT) software module.

The examination printout for SPARK-based examinations is essentially the same as that of other threshold examinations.

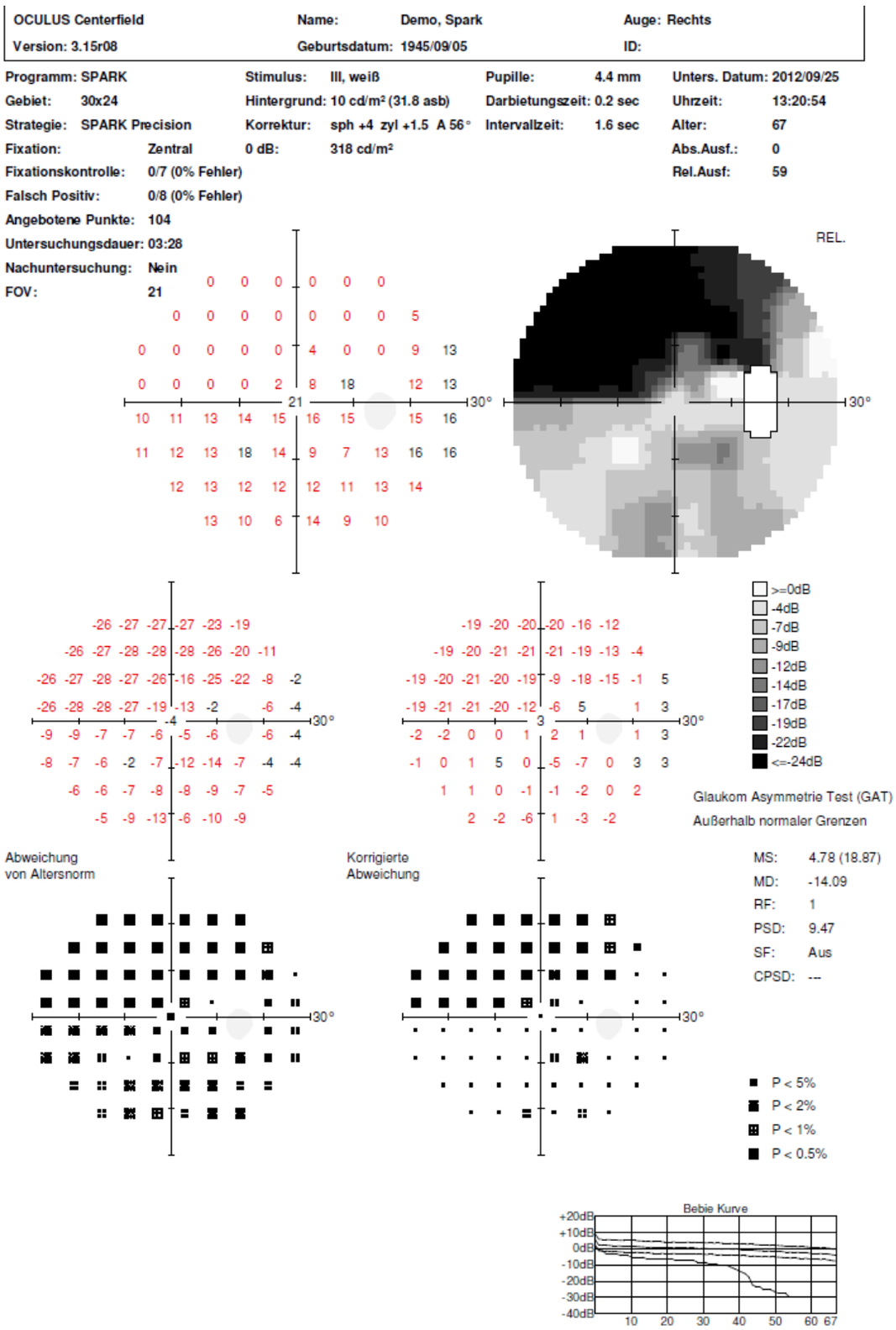



Figure 50, Examination printout from a glaucoma patient examined with a Centerfield® perimeter using SPARK

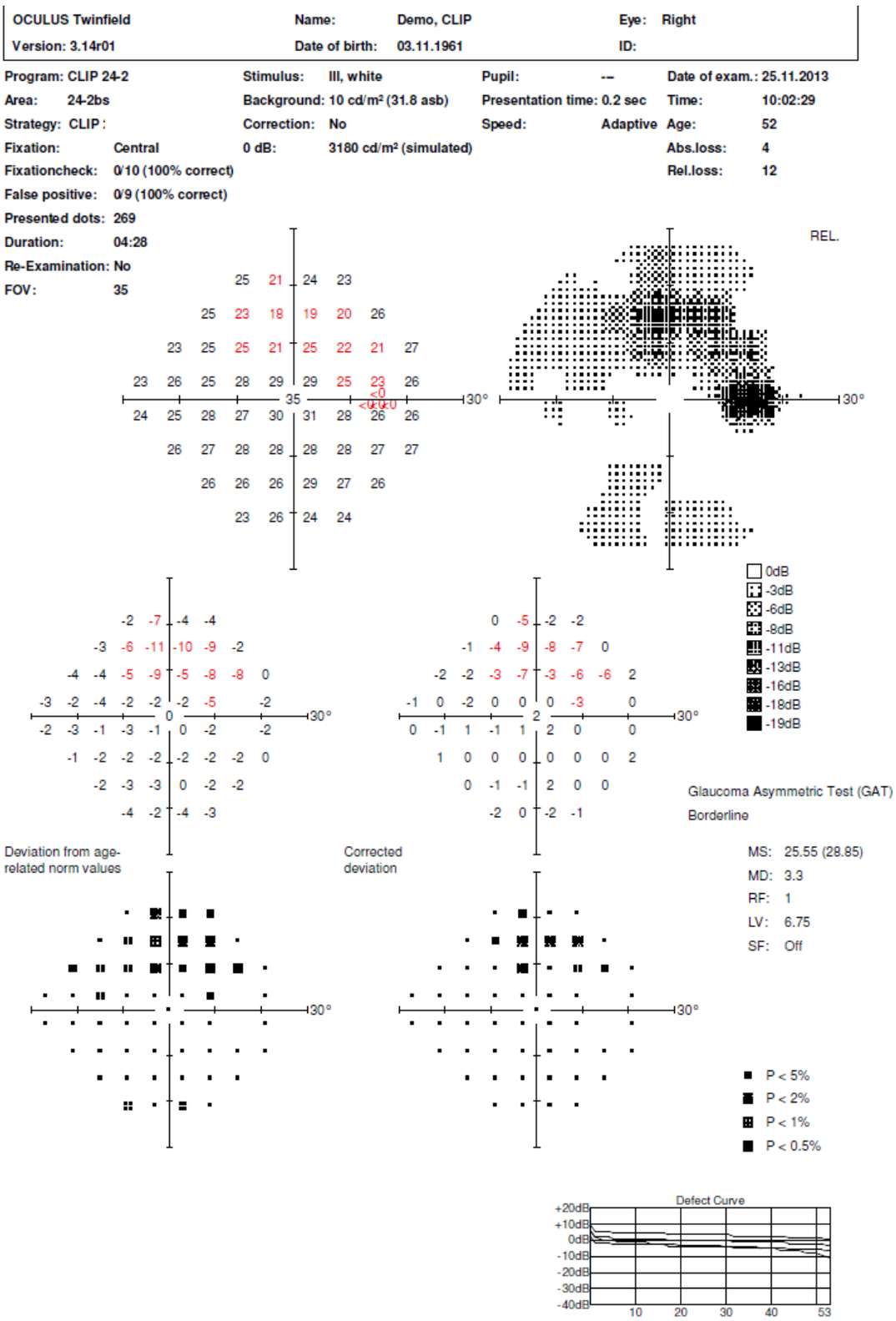



Figure 51, Results of a CLIP examination of a glaucoma patient using the Twinfield®

### 7.1.2. CLIP Strategy

The principles of the CLIP (Continuous Light Increment Perimetry) Strategy have been covered in Chapter 3.4.1.3. CLIP Strategy. It will suffice to say that CLIP-based examinations take little time and are surpassed only by SPARK in this respect. Threshold examinations performed with CLIP are the most agreeable to patients because the stimulus remains visible during most presentations (once a certain luminance level has been reached), whereas whereas commonly with other threshold strategies the stimuli are presented more and more below the patient's sensitivity threshold in the course of an examination. An important point for the examiner to consider in selecting an examination strategy, however, is that CLIP yields its best results with very cooperative patients. Although CLIP is mainly used for glaucoma examinations, this is by no means its only application area, as it can be used just as well for visual field examinations in any other situation. Especially in patients who cooperate poorly with other strategies CLIP will often still produce usable results.

The examination printout from a CLIP-based examination (see Figure 51, Results of a CLIP examination of a glaucoma patient using the Twinfield® for an example) is principally the same as those from other threshold examinations.

## 7.2. Assessment of the Visual Field

Interpreting and classifying visual field results can be a very challenging task in some situations. OCULUS provides unique support to examiners also in this regard.

### 7.2.1. Glaucoma Staging Program (GSP)

The Glaucoma Staging Program (GSP) was developed by D. Wroblewski, PhD and his collaborators[1] with the explicit aim of facilitating early glaucoma detection using solely the results of a visual field examination. This novel evaluation module performs a thorough assessment of visual field data using modern algorithms of pattern recognition. Besides providing a unique tool for early glaucoma diagnosis, GSP can be used to verify and crosscheck evaluations of clinical results. Further information on the GSP is available from the sources quoted above and from the OCULUS perimeter manuals.

Below is a summary of the main advantages of GSP:

- Unique pattern recognition: No other manufacturer offers an analysis tool even similar to GSP in its products.
- Expert advice included: Thanks to GSP the general ophthalmologist can consult the opinion of leading glaucoma experts in assessing examination results.
- Sensitivity beyond human limits: GSP notices subtle changes and patterns in the visual field undetectable to human observers.
- Clear results display: GSP uses self-explanatory green-yellow-red colour coding to present the results in an easily understandable manner.

An example of how results are displayed with GSP is given in Figure 52 below showing the results of an examination of a patient's left eye. All visual field indices are within their normal ranges. As one would expect, GSP classifies the visual field as largely normal. Its verbal assessment reads: "A glaucoma expert would classify this visual field as "normal" with a 90% likelihood.

1 D. Wroblewski et al, Graefes Arch Clin Exp Ophthalmol (2009)

The enormous power of GSP is then revealed in the second diagram. Here the pattern recognition function tells us that the visual field under examination is similar to that of a glaucoma suspect or a pre-perimetric glaucoma patient with a likelihood of 78% (12% and 66% respectively). This kind of conclusion would be absolutely impossible without the use of GSP. Based on a conventional assessment the patient would be said to have a completely normal visual field.

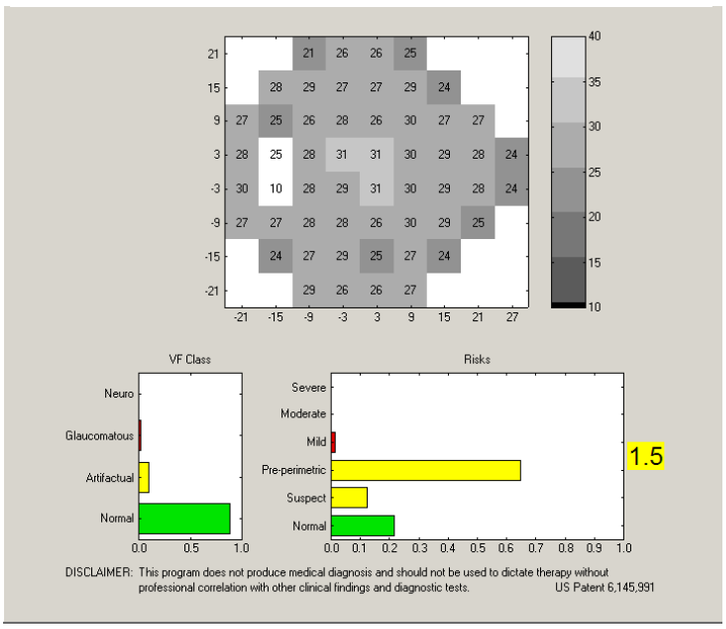



Figure 52, Representation of suspicious visual field findings in the GSP overview display. The visual field index VFI is accordingly highlighted in yellow (warning).

## 7.2.2. Improved Glaucoma Staging System (only available on the Easyfield®)

The improved Glaucoma Staging System (GSS 2) was developed by Paolo Brusini, MD [2]. This classification system is based on the fairly simple idea of representing the visual field under examination on a two-dimensional map showing the Mean Defect (MD) versus the Pattern Standard Deviation (PSD) (see Figure 53, The improved Glaucoma Staging System as it was presented in the first publication of the method in 2006. and Figure 54, Evaluation using the improved Glaucoma Staging System as it appears on the examination printout of the Easyfield®). The location of a test point on the colour map is thus defined by the values of these two perimetric indices measured at that point. The diagram shows clearly distinguishable regions representing different stages (0 to 5) of visual field loss. Defects found are additionally classified as generalized, local or mixed.

In a recently published study comparing different systems for classifying the severity of glaucoma the authors concluded that "Given our overall results and its ease of use, Brusini and Filacorda's Enhanced Glaucoma Severity Staging system may be the best choice for its ease of use for clinicians and researchers alike".[3]

2 P. Brusini, S. Filacorda, J. Glaucoma (2006) 15: 40-46
3 Minna Ng, PhD et al, J. Glaucoma (2012)

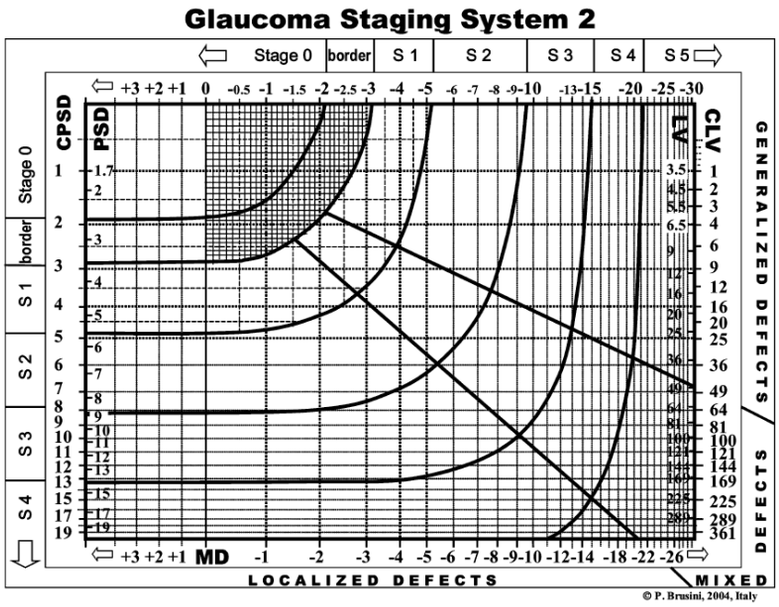



Figure 53, The improved Glaucoma Staging System as it was presented in the first publication of the method in 2006.

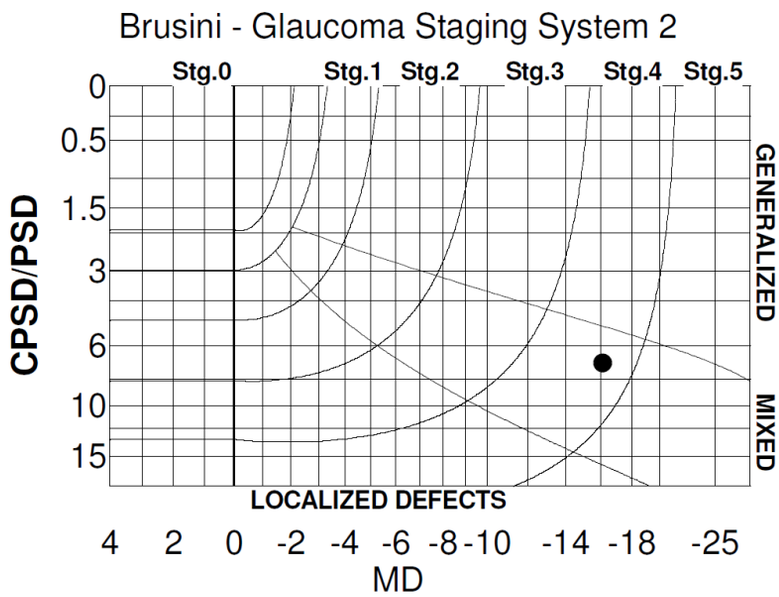



Figure 54, Evaluation using the improved Glaucoma Staging System as it appears on the examination printout of the Easyfield®

## 7.3. Progression Analysis of the Visual Field in Glaucoma

It is widely agreed that it is not sufficient to merely document the presence of visual field defects but that information is also needed on their development over time. After all, glaucoma is essentially a progressive disease. It is indispensable to accurately assess any deterioration in visual field function in order to be able to establish the right treatment for preserving the patient's eyesight as best possible.

### 7.3.1. Threshold Noiseless Trend (TNT)

This progression analysis method was developed by Prof M. González de la Rosa [4] , the creator of the SPARK Strategy (Figure 55, Main display of the TNT analysis software. The final report on the visual field test series is shown on the right.). TNT performs a quantitative statistical analysis of changes in visual field examination results over time. The software takes into account all threshold examinations performed with any of the test patterns 30-2, 30x24 and 24-2 [5]. From the results of these examinations TNT extracts threshold values of low variability which it then uses for carrying out trend analyses on local ("point-by-point regression") and global results ("MD regression") as well as the Bebié curve ("DC regression).

A detailed description of the TNT method would go beyond the scope of this guide. For more information about this software please refer to the user manual of any OCULUS perimeter. The following is only a summary of its main advantages:

- High detection sensitivity: TNT can detect early changes in visual field function that are consistently missed by methods based on pattern deviation[6].
- The more examinations, the more accurate: Unlike methods which merely consider the present moment, trend analyses make full use of the data pool of earlier examinations.
- Increased significance: Since there is no one objective gold standard for assessing changes in visual field function over time, the TNT analysis method instead relies on three unequivocal objective criteria.
- Unique features: TNT features purpose-designed analysis methods such as one for regression analysis of the defect curve, as well as defined objective progression criteria for point-by-point regresson analysis.

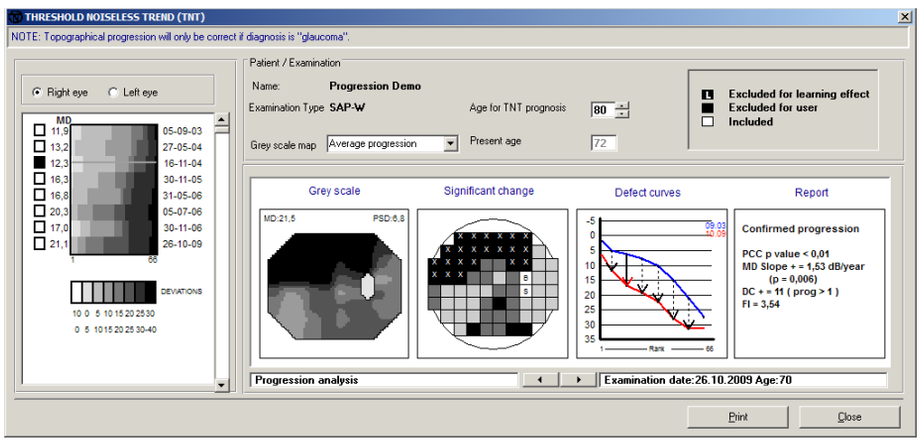



Figure 55, Main display of the TNT analysis software. The final report on the visual field test series is shown on the right.

4 M. González de la Rosa, Br J Ophthalmol (2008) 92:1564-1565
5 Needless to say, TNT also works optimally for SPARK-based examinations.
6 V T Diaz-Aleman et al, Br J Ophthalmol (2009) 93:322-328

# 8. The Peripheral Visual Field

In clinical practice visual field examinations are usually restricted to the central visual field (conventionally up to 30° eccentricity). In some cases, however, further telling information can be gained from an examination of the peripheral visual field. For example, in patients with visual defects suspicious of having a neurological cause, an examination of the peripheral visual field can provide information on the magnitude of the primary cause behind the defects observed. Furthermore, examinations of the peripheral visual field may sometimes be required by law (such as by driving licence regulations in some countries).

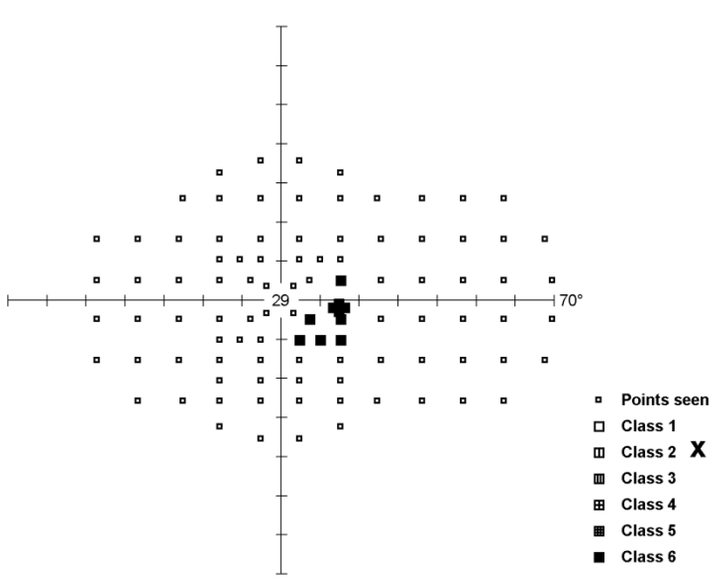
This short chapter presents a few examples of typical examination findings for the peripheral visual field. The examination printouts differ somewhat in appearance from those shown in Chapter 6, because the test patterns and examination strategies used differ from those for the central visual field. Needless to say that the examples given do not reflect the wide range of findings encountered in clinical practice, and the diagnoses to which they give rise could just as well come about through findings of an entirely different kind. The sole purpose of presenting these examples is to make the reader familiar with the examination printouts of OCULUS perimeters.

## Example 13: Enlarged blind spot

| | | | |
|---|---|---|---|
| OCULUS Twinfield | Name: | Demo, Vergr. Bf | Eye: Right |
| Version: 1.75 | Date of birth: | 10/23/1973 | ID: |

| | | | |
|---|---|---|---|
| Program: unknown | Stimulus: III, white | Pupil: --- | Date of exam.: 07/02/2002 |
| Area: FeV-70 | Background: 10 cd/m² (31.5 asb) | Presentation time: 0.2 sec | Time: 13:57:14 |
| Strategy: Classes | Correction: No | Interval time: 0.6 sec | Age: 28 |

Fixation: Central
Fixationcheck: 0/6 (100% correct)
False positive: 0/4 (100% correct)
Presented dots: 121
Duration: 03:47
FOV: 29



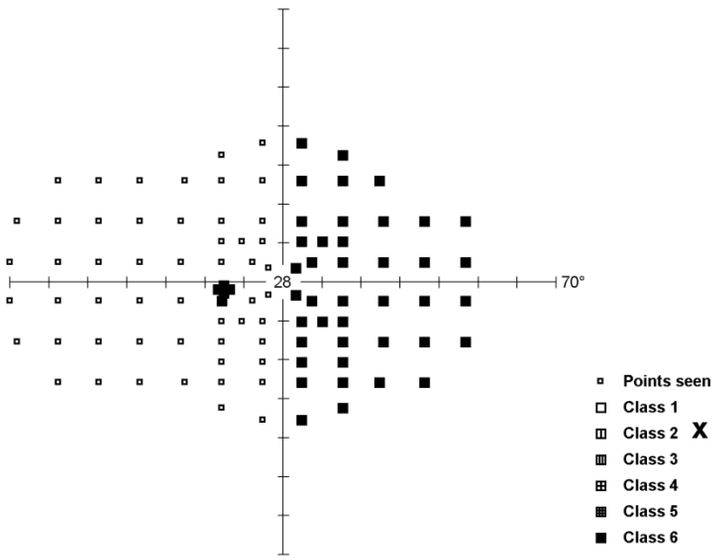

This examination was performed on a person undergoing a driving aptitude test in order to obtain a commercial driving licence. The examination printout shows an enlarged blind spot which is probably attributable to glaucoma. The examination was performed with a suprathreshold strategy, so no threshold values are given.

## Example 14: Hemianopsia

| | | | | | |
|---|---|---|---|---|---|
| OCULUS Twinfield | | Name: | Demo, Halbseitenausfall | Eye: | Left |
| Version: 1.75 | | Date of birth: | 10/23/1973 | ID: | |

| | | | | | |
|---|---|---|---|---|---|
| Program: unknown | | Stimulus: | III, white | Pupil: | --- |
| Area: | FeV-70 | Background: | 10 cd/m² (31.5 asb) | Presentation time: | 0.2 sec |
| Strategy: Classes | | Correction: | No | Interval time: | 0.6 sec |
| Fixation: | Central | | | | |
| Fixationcheck: | 0/9 (100% correct) | | | | |
| False positive: | 0/5 (100% correct) | | | | |
| Presented dots: | 170 | | | | |
| Duration: | 04:25 | | | | |
| FOV: | 28 | | | | |

| | |
|---|---|
| Date of exam.: | 07/02/2002 |
| Time: | 13:52:26 |
| Age: | 28 |




The diagram above shows a case of hemianopsia. This finding is often the result of a neurogical disorder such as a stroke. This examination was also performed with a suprathreshold strategy, which explains why the examination printout gives no threshold values nor any other maps or test patterns.

# List of Figures

# Table List

# Examples

# List of Abbreviations

| | |
|---|---|
| abs. | absolute |
| AMD | age-related macular degeneration |
| asb | Apostilb |
| BPFP | Blue preferential perimetry |
| CAR | Carcinom-assoziierter Retinopathie |
| cd | Candela |
| CLIP | Continuous Light Increment Perimetry |
| CPSD/PSD | Corrected Pattern Standard Deviation |
| dB | Decibel |
| DLS | Differential Luminance Sensitivity |
| FOV | foveal luminance threshold |
| GAT | Glaucoma Asymmetric Test |
| GH | General Height |
| GHT | Glaucoma Hemifield Test |
| GSP | Glaucoma Staging Program |
| GSS | Glaucoma Staging System |
| LCD | Liquid Crystal Display |
| LDK | Leuchtdichteklasse |
| LDS | Light Difference Sensitivity |
| LED | Leuchtdiode |
| LUE | Lichtunterschiedsempfindlichkeit |
| LV | loss variance |
| MD | Mittlere Abweichung/ Defekttiefe |
| MS | Mittlere Empfindlichkeit |
| OD | right Eye |
| OS | left Eye |
| PhD | Doctor of Philosophy |
| PSD | Pattern Standard Deviation |
| rel. | relative |
| RF | Reliability Factor |
| RIP | Red increment perimetry |
| SAP | automated Standard perimetry |

# List of Abbreviations

| | |
|---|---|
| SF | Short-Term Fluctuation |
| SI | International system of units |
| SWAP | Short Wavelength Automated Perimetry |
| TNT | Threshold Noiseless Trend |
| VFI | Field of index |

# Index

# Afterword

We hope that reading this guide has enabled you to learn more about perimetry in general and about the results generated by OCULUS perimeters in particular. At the same time, it can hardly be overemphasized that this guide should not remain your only source of information about visual field examinations. Its purpose is rather to give you a short overview of the field. It is intended to encourage you to delve into questions of detail on the theoretical background of perimetry and to grow your practical experience through using OCULUS perimeters in a variety of clinical fields and tasks.

No single manual, nor even an institution, can claim to convey to you everything worth knowing about perimetry. Although we as a manufacturer do all we can to provide you with all the information you might possibly need, sooner or later you will be confronted with questions to which you will not find an answer in the documentation of your OCULUS instruments. Whenever this happens we encourage you to contact a member or partner of the worldwide OCULUS sales network or our support team at our headquarters in Wetzlar, Germany. We look forward to answering your questions on the phone or by email and providing you with new information about OCULUS perimeters.

We sincerely hope that you derive great benefit from the abundant possibilities offered by our perimeters and that working with this original OCULUS instrument will be a lasting source of professional joy and satisfaction to you.

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